

**United States Air Force
Scientific Advisory Board**



**Report on
Global Air Navigation Systems
Volume 2: Detailed Findings**

SAB-TR-97-02

September 1998

Authorized for Public Release - September 1998

This report is a product of the United States Air Force Scientific Advisory Board Ad Hoc Committee on Global Air Navigation Systems. Statements, opinions, recommendations, and/or conclusions contained in this report are those of the Ad Hoc Committee and do not necessarily represent the official position of the USAF or the Department of Defense.



DEPARTMENT OF THE AIR FORCE
HEADQUARTERS UNITED STATES AIR FORCE
WASHINGTON D.C.

26 August 1999


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FROM: HQ USAF/SB
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SUBJECT: USAF Scientific Advisory Board Study on Global Air Navigation Systems, Volume
2: Detailed Findings

I am pleased to forward a copy of this 1998 SAB study report for your review. This report presents the results of a study chartered by the Air Force Chief of Staff and the Secretary of the Air Force to identify, define, and categorize the modifications and additions necessary for Department of Defense aircraft and ground systems to operate in the new global civil aerospace architecture environment in terms of urgency and utility. The study examined the needs and possibilities for navigation systems to be used by the USAF of the 21st century. The study group identified a number of findings relative to current Air Force operations and suggested several general recommendations that the Air Force might consider.

This report can also be downloaded electronically from the SAB web site at:
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ROBERT J. SCHRAEDER JR., Colonel, USAF
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Scientific Advisory Board**



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13. ABSTRACT (Maximum 200 Words) This report presents the detailed findings of the 1997 Air Force Scientific Advisory Board (SAB) study on Global Air Navigation Systems (GANS). Major issues and requirements for GANS are discussed, including capabilities vs. equipment, the impact of GATM noncompliance, technology needs, proposed acquisition and management strategy with the Air Force in leadership role, ground and future service provider infrastructure including ATC, international aspects, liability, demonstrations, datalinks, GPS/INS technical information, and airspace deconfliction implications for the Department of Defense (DoD). Changes in the global civil airspace architecture will necessitate changes in Air Force equipment and procedures. The GANS Study attempted to identify, define, and categorize the modifications and additions necessary for DoD aircraft and ground systems to operate in the new environment in terms of urgency and utility. Needs and possibilities for navigation systems to be used by the USAF of the 21 st century were examined. Departure, en route, and landing procedures and requirements were studied. New GATM requirements will affect space and ground systems as well as aircraft.				
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Chapter 1—Major Issues in GANS

International airspace architecture is undergoing significant changes and will continue to do so in the next 15 years. This change will have a significant impact on DoD operations if actions are not taken to assure that 15,000 DoD aircraft can operate in this evolving environment. DoD must anticipate and adapt to changes in communications, navigation, surveillance, and air traffic management.

Making the transition to GANS confronts DoD with some major issues, including:

- Global air traffic management (GATM) requirements and timing
- Establishment of an orchestrated investment strategy
- The DoD role in shaping the future global airspace architecture
- Military utility of GATM technologies

1.1 INTRODUCTION

Air Force leadership can leverage the new technologies to exploit their military aspects and influence the civil concepts to support the necessary flight requirements. An example of leveraging new technology is seen in the National Command Authority's decision to make the military Global Positioning System (GPS) available for civilian use worldwide. This allowed the International Civil Aviation Organization (ICAO) Future Air Navigation Systems (FANS) committee in 1989 to recommend a new civil aviation communications, navigation, and surveillance (CNS) architecture with GPS as the cornerstone. While ICAO could not specifically adopt GPS as the international standard, it did endorse Global Navigation Satellite Systems (GNSS), which means GPS plus augmentations. If the United States had not offered GPS for civilian use (with no direct user fee), ICAO could not have endorsed the CNS architecture that is now evolving. The resultant civilian exploitation of that decision has obliged DoD to make investments to satisfy not only military requirements but the requirements of organizations and entities not under its control. Related efforts by the ICAO and the Federal Aviation Administration (FAA) to increase airspace capacity and enable more efficient air routing have exacerbated this challenge.

New investments are necessary if DoD is to avoid being excluded from airspace—nationally and internationally—as the new CNS systems are fielded. Airspace denial—to assure flight safety and interoperability with the ground infrastructure—is based on the lack of capability to meet the mandates of the civil authorities controlling the airspace. These national mandates will be promulgated in the near and far terms, with major impacts on DoD air traffic if DoD does not adapt.

Justification for the investment in new CNS technologies includes:

- Airspace system capacity increase
- Economic benefits of operation in the optimum flight envelope
- Upgrade or elimination of the high-cost/labor-intensive ground-based air traffic control (ATC) system
- Air traffic service provider growth in developing countries
- Reduction in operations and maintenance (O&M) costs for ground infrastructure
- Technology substitutions for controllers and maintenance personnel
- Expanded capacity in overloaded communications networks and overused frequency spectra
- Transition from analog to digital systems

Many of these benefits, at first glance, provide only limited benefits to DoD users. However, a more in-depth review of the issues reveals that DoD adoption of some of these technologies would not only assure civil compliance, but also could be used to gain a military advantage. This situation therefore demands that the sponsors of GANS studies convince decisionmakers of the need to equip selected DoD aircraft with the technology necessary to assure unrestricted global access and of the operational advantages that would be achieved as a byproduct of these investments. By joining the best attributes of these emerging GANS mission area capabilities with those of more traditional warfighting capabilities (such as Link 16—also called TADIL J—for air-superiority operations), a powerful synergy can be developed for the warfighter.

1.1.1 GANS Requirements and Timing

The requirements for CNS-related systems are being driven by the decisions of national and international organizations. Requirements are also being driven by the obsolescence and technical and labor-intensive inefficiencies of the current systems and a growing realization of the cost-avoidance opportunities available to the service providers and users by transitioning to a CNS-dominated architecture. Other requirements are being driven by political and economic events in various regions of the world and, in some instances, individual countries. Additionally, the density of national boundaries in places such as Europe leads to duplication of frequency assignments due to range overlap.

Most plans for transition from the current infrastructure to one dominated by CNS provide for a phased approach; some of the plans make exceptions for noncompliant state aircraft. These exceptions are not guaranteed; rather, they are based on controller workload and traffic density. There can be no doubt, however, that eventually all aircraft, including state aircraft, must achieve compliance to the extent required by their missions, or they will burden the system such that they will be excluded from selected areas.

The perceived uncertainty of the implementation plans—especially the timing of required compliance—is understood, and this, combined with the lack of urgency and the implied waivers for state aircraft, makes it difficult to persuade decisionmakers to fund GATM when high-priority “must fund” issues compete for limited funds. The Air Force has faced similar challenges before: INS requirements in the North Atlantic, Mode 3C identification, friend or foe (IFF) capability, and VHF channel-splitting to 50 kHz, then 25 kHz. All such challenges were resisted or ignored until the reality of airspace exclusion forced a crash program to equip aircraft, with the added expense of rushed procurement and integration. The Air Force should not—must not—repeat this mistake. The reality of the transition from current systems to space-based systems, along with the emerging mandates associated with this transition, provides sufficient confidence to begin developing an acquisition strategy.

The best information available for timing these investments comes with combining input from

- Observing the civil requirements process
 - Implementing schedules promulgated by national and international aviation authorities
 - Developing standards and certification criteria
- Judging the availability of compliant equipment and infrastructure
- Anticipating the level of compliance in the civil aviation community

1.1.2 Establishing an Orchestrated Investment Strategy

Investment strategy must take into account aircraft mission, life-cycle cost, and the impact of noncompliance on mission execution. Should the investment in aircraft assigned to basic pilot training, for example, be identical to that made in aircraft assigned to a tactical or mobility support mission? Should all Air Mobility Command (AMC) aircraft be provided with a total modernization package, or should modernization investments be made based on the specific mission assigned and the environments in which the aircraft will operate?

The benefit to DoD of joint acquisition and common retrofit of like technologies rather than Service-unique acquisition should be explored. Where the end-state architecture is not clear, DoD should participate actively with the FAA in technology demonstration programs that assist in crystallizing industry consensus while, at the same time, providing the military with firsthand knowledge and experience of the emerging technology and standards. To support these demonstrations, the feasibility of portable equipment of selected platforms (pods) should be explored. Pods are a method of temporarily augmenting the contents of an integrated capability. A limited investment in the high-risk or uncertain technologies implemented by the “pathfinder” concept (a fully equipped aircraft that leads nonequipped aircraft to a destination) will ensure continued DoD input on final design with a limited investment until the risk is mitigated or the concept is canceled.

The transition to GATM technologies by all segments of aviation worldwide provides a unique opportunity to share ideas, concepts, and resources between the civil and military communities. The cost/benefit potential of this concept and the partnerships that will result from it demand its consideration.

1.1.3 DoD's Role in Shaping the Future GANS Architecture

As chartered by DoD directive 5030.19, the focal point between DoD and national and international bodies involved in ATC and airspace management issues with joint-Service interest is the DoD Policy Board on Federal Aviation (PBFA). The DoD directive tasks the Secretary of the Air Force to provide support to the PBFA Executive Director and staff. The PBFA has done a good job of protecting DoD's interest, but the resources available to discharge the large and complex emerging responsibilities are insufficient. As a result, most CNS issues that are being worked are reactive rather than proactive. The organizational position of the DoD Policy Board—on the staff of Air Force XO—causes some concern for the other Services. The understandably competitive environment among the Services frequently raises questions about the impartiality of some PBFA decisions.

The Executive Director of the PBFA has also been assigned as the chief lobbyist for the United States in marketing to the world the advantages of a common civil/military system for ATC and airspace management. This assignment provides an opportunity for DoD to influence—at the international policy level—the GATM end-state architecture and the timing of its implementation. However, recognizing that regional implementations are taking place and will likely continue to do so, DoD must also participate in regional navigation planning groups, both official and informal, where actual planning and implementation are carried out.

In executing its responsibility as outlined in DoD Directive 5030.19, the Air Force must decide between two alternatives:

- Option 1: Maintain the current manning/resources level committed to PBFA support and continue to react to new civil systems as a compliance requirement. This approach can be summarized as “FAA/ICAO, tell me what I need on my aircraft and when I need it, and I will comply.”
- Option 2: Provide the PBFA secretariat with the resources to interact proactively with the FAA/ICAO to influence the future CNS/air traffic management (ATM) course related to technology selection, architecture, standards, implementation strategy, timing, and transition strategy. This option can be summarized as “FAA, let us work together to chart our future national course.”

The panel believes that Option 2 is the correct path. The PBFA’s potential to influence the future will not be realized without an infusion of resources. Personnel are necessary not only to serve as action officers working specific issues, but also to serve as arms and legs to attend meetings, nationally and internationally, where opportunities to shape the future course are now being lost because of a lack of representation. This augmentation can be in the form of active-duty personnel, contractors, or a combination of the two. Some contractor representation is recommended for continuity. In addition, senior leaders must resolve Service concerns about the PBFA’s leadership being on the Air Force staff rather than the Office of the Secretary of Defense (OSD) staff.

Each Service is working GATM-related issues more or less independently. One of the benefits of the study sponsored by the Air Force Scientific Advisory Board (SAB) has been joint-Service participation. Action must be taken to enhance the joint approach to GATM issues. The OSD is exploring a joint approach. The GATM Operational Requirements Document, which has a potential joint designator, will be briefed to the Joint Requirements Oversight Council (JROC) in the near future. The cost savings of a joint approach, with its inherent opportunity for bulk acquisition, tailored system integration, and a common acquisition strategy, is a benefit.

The DoD organization that will realize the initial and greatest degree of airspace exclusion is the AMC. Logic therefore suggests that the Services enter a Memorandum of Agreement appointing USCINTRANS as the executive agent for DoD to represent all Service interest in GATM issues. Requirements of the other Services and even of the rest of the Air Force will not parallel the AMC’s requirements, but AMC, as the organization impacted by every aspect of GANS, must be familiar with each issue. This familiarity can then be used to brief other elements of DoD to the extent necessary for an informed decision. For this to occur, Air Force leadership must sponsor AMC in this role.

The applicability of the benefit of and need for each GATM technology is a decision to be made by the affected Service or subset of a Service based on mission assignment, concept of operations (CONOPS), and the ability to accept or avoid the impact of noncompliance for operational and economic reasons.

1.1.4 Military Utility

GATM technology will provide near-real time worldwide communications and precision position information for command and control (C²), in-transit visibility, asset visibility, battlespace management, stationkeeping, refueling, navigational guidance, and weapons delivery, among other benefits—all derived from the investment to retain commonality with the controlled environment that will dominate the world’s airspace structure. There is no doubt of these benefits, but decisionmakers, faced with choices involving flight times, steaming hours, and

operations tempo and personnel tempo, need to be persuaded that the tactical advantages and cost savings from system commonality justify GATM investment.

A strategy must be adopted that can trace the operational deficiencies being identified by operational units, be they users or providers of services, to the benefits to be realized by the acquisition and deployment of GATM technologies.

Currently, the Services lack the ability to deploy precision recovery capability to support operations in a hostile or bare-base environment. This issue is being worked in the Joint Precision Approach and Landing System (JPALS) initiative. The results, now undergoing analysis of alternatives (AoA), will answer some of the opposition to GATM acquisition and should be used as an example of an investment that will result in operational efficiency and a cost-effective solution and will enhance joint-Service operations.

1.2 Air Traffic Control

The mission of Air Force ATC is to facilitate the safe, orderly, and expeditious launch and recovery of aircraft supporting Global Reach—Global Power. To support national objectives, the Air Force furnishes ATC services to U.S. and allied aircraft with radar approach controls (RAPCONs), ATC towers, navigation aids (NAVAIDs), and precision approach and landing systems (PALS). These facilities and equipment, as well as the people who operate and maintain ATC systems within the Air Force, constitute the ATC and Landing Systems (ATCALS) functional area.

ATCALS provide the operational conduit for all contingency operations or war. During Operations Desert Shield and Desert Storm, the Air Force deployed seven RAPCONs, two ATCTs, seven NAVAIDs, and 330 personnel to manage the deployment and redeployment of combat forces as well as the daily ATC operations.

The future ATC environment in which the Air Force must operate will experience sweeping changes—the most since surveillance radar was introduced for ATC in the 1950s. In fact, the next 5- to 15-year period will be marked by the turmoil of transition. This will not be unique to the Air Force; it will affect any organization, national or international, engaged in providing ATC services or supporting systems used to provide ATC services. The worldwide ATM structure is evolving. There is a great emphasis within the aviation community on moving from ground-based, analog systems to an environment primarily dependent on space-based, digital technology. Concomitantly, there will be a shift from heavy reliance on the ground infrastructure for separation and sequencing of aircraft to the airborne side as flight becomes more autonomous. Nevertheless, the need for the ATC ground infrastructure will not go away entirely nor as rapidly as many would like to see.

Thus, as a service provider in this new ATM environment, the Air Force must upgrade or replace technologically and physically obsolete 20- to 30-year-old systems that are logistically difficult to maintain if the Air Force wants to remain a player. Interoperability with host-nation civil aviation counterparts will be crucial to providing seamless ATM services. Furthermore, as the Air Force and other Services leap forward to capture advances in GATM avionics technology, the ground infrastructure must likewise evolve to interface with the future air and space components to ensure unrestricted access to domestic and international airspace for warfighters.

The Air Force also faces another challenge: The Air Force is burdened by an ATC logistics support infrastructure beset by a proliferation of ATCALS performing similar functions. For example, the Air Force has two fixed-base airport surveillance radars (ASRs) in the inventory. A third and completely different ASR is being procured under an existing DoD/FAA contract. As defense dollars shrink, as Air Force manpower shrinks, and as technology improves, the Air Force needs to transition from the old way of doing business to more robust, lean, and technologically innovative methods. This may entail radical changes in the way ATC is conducted in the future. Finally, the Air Force may have to maintain some residual capability to operate in an environment in which our access to satellite-based navigation systems is restricted, degraded, or denied to the Air Force by enemy action.

Chapter 2—Requirements

2.1 INTRODUCTION

The intent of Federal, DoD, and Air Force regulations regarding compliance of military aircraft with civil regulations is clear: in general, military aircraft operating in civil-controlled airspace must comply with U.S. national, foreign national, and international regulations and standards, with exceptions in the case of a military emergency or other urgent military necessity affecting national security. This intent is borne out by a 1996 position paper issued by the two Major NATO Commands (MNCs) on “Civil/Military Use of the Airspace,” which recognizes the need for military aircraft to comply to some extent with emerging civil ATC requirements in Europe.

The following subsections summarize regional plans and timelines for the Pacific, the North Atlantic, the U.S. National Airspace System (NAS), and Europe.

2.2 PACIFIC IMPLEMENTATION PLANS AND SCHEDULES

The Asia and Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG) is the official ICAO planning group for that region. APANPIRG comprises 16 member states in Asia and the Pacific; it holds annual meetings to harmonize local plans with regional and global plans. Much of the legwork for development and implementation of new CNS/ATM systems and procedures in the Pacific is actually carried out by the Informal South Pacific Air Traffic Services (ATS) Coordinating Group (ISPACG) in the South Pacific and the Informal Pacific ATC Coordinating Group (IPACG) in the North and Central Pacific. These groups are not a substitute for the official ICAO process, and their work must eventually be coordinated through APANPIRG or ICAO’s Bangkok regional office, but they can meet more frequently than official ICAO groups and can speed the official process by working out issues and implementation details ahead of time.

The FAA and the Japan Civil Aviation Bureau (JCAB) are the major providers of ATS in the North and Central Pacific. In January 1996, the FAA Administrator and the Director General of the JCAB agreed to implement controller-pilot datalink communications (CPDLC) and automatic dependent surveillance (ADS) in the North and Central Pacific and to begin ADS trials in October 1997. The FAA and JCAB also agreed to accept the guidelines for CNS/ATM implementation developed at the ninth meeting of the Informal Pacific ATC Coordinating Group (IPACG/9) in November 1995. This agreement paved the way for implementation of required navigation performance (RNP) airspace and reduced separations in the North and Central Pacific beginning in 1998. The IPACG strategy calls for mandating a CNS capability (CPDLC, RNP-4, and ADS) to achieve 30-nmi reduced separations in dense oceanic airspace by 2003. This will be based on a FANS-1 infrastructure and applications, since FANS-1 is now in place or being acquired for the Oakland, Anchorage, and Tokyo centers. It is unlikely that the CNS requirements for separations of 30 nmi laterally and longitudinally (30/30 separation) will be defined in further detail until RNP-10 and reduced vertical separation minima (RVSM) implementations are well under way.

2.2.1 Communications Requirements

The basic new communications requirement for the Pacific is an oceanic datalink communication system that can support the CPDLC and ADS applications. In FANS-1, only a single datalink is needed—with a high-frequency (HF) voice backup—and only Inmarsat aeronautical satellite communications has been approved by ICAO and received operational approval from civil aviation authorities for beyond-line-of-sight use. It is anticipated in the industry, however, that eventually dual independent datalinks (a primary and a backup system) will be required for access to 30-nmi reduced-separation oceanic tracks and in-flight rerouting. This expectation is based on precedent: redundancy is typically required for ATC systems—as called out in numerous sections of the Federal Aviation Regulations (FAR), the 1994 “oceanic equipage and benefits” letter sent to the Air Transport Association by FAA Administrator David Hinson,¹ and general system availability considerations (addressing no single point of failure).

The minimum aviation system performance standards (MASPS) for required communications performance (RCP) are still in development. The MASPS will define the parameters (such as availability, delay, and accuracy) needed to characterize communication system performance. The MASPS will not define the RCP parameters (such as what message delay is acceptable for ATC datalink messages in oceanic airspace, en route airspace, and so on) needed to support safe operations in different airspace types. Those criteria will need to be developed. Since the performance requirements for the communication systems have not been defined, the systems needed have not been specified. It is possible that dual satellite systems, a combination of satellite and high-frequency datalinks (HFDL), or dual HFDL systems will be used. Within line of sight, the VHF aircraft communications addressing and reporting system (ACARS) can be used to support FANS-1 datalink applications. Line-of-sight connectivity is available in much of the Anchorage Flight Information Region.

Inmarsat Aero is already approved for use as a beyond-line-of-sight ATC datalink. The standards and recommended practices (SARPs) for aeronautical-mobile satellite service have been incorporated in ICAO Annex 10, and the Inmarsat datalink has been certified for ATC use as part of FANS-1. The process of getting HFDL approved for ATC use has begun: ICAO approved the HFDL SARP in April 1998. The international approval process should be complete by spring 1999, and a manual with compliance guidelines published in the fall of that year.

It is generally agreed that a voice backup to the datalink will continue to be required. For FANS-1, the backup is HF voice. This system does not provide direct communication between the pilot and the controller; the air-to-ground calls are made to radio operators at Aeronautical Radio Inc. (ARINC) HF ground stations who transcribe the position reports and send them via landlines to the appropriate oceanic ATC center.

There is increasing evidence that a direct voice link between the pilot and the controller will be required for reduction of aircraft separations to 30 nmi. Both the International Federation of Air Traffic Controllers Associations and the International Federation of Airline Pilots Associations have said they will not endorse the reduction of separation standards below 50 nmi unless direct controller-to-pilot satellite voice communication is required on aircraft for controller intervention.

¹ The schedules in the Hinson letter are no longer valid. However, the letter still provides insight into the benefits that can be implemented in oceanic airspace and the equipage considered necessary to support those benefits.

FAA spokesmen have said they believe satellite voice is not needed for 50/50 separations, but may be for 30/30.

There appears to be disagreement within ICAO about the necessity of a direct pilot-to-controller voice link for safe reduction of separations, with the ADS Panel arguing that a satellite voice link is needed and the Review of the General Concept of Separations Panel (RGCSP) disagreeing. The question of a future requirement for direct pilot-controller voice communication for access to certain oceanic tracks is still unresolved.

Currently the only system approved for beyond-line-of-sight direct pilot-to-controller voice communication is the Inmarsat Aero-H high-gain system. Next-generation satellite systems are a possible future alternative. Motorola has stated its intention to provide a full range of aeronautical services, including ATC, over the Iridium low-earth orbit (LEO) satellite system, and has filed with the FCC for the appropriate spectrum in the aeronautical mobile satellite (route) service (AM[R]S) band. SARPs for next-generation satellite systems are being developed for CPDLC and other beyond-line-of-sight ATC datalink services.

2.2.2 Navigation Requirements

ICAO member states implemented RNP-10 on the north Pacific tracks and transition routes and over the Tasman Sea on 23 April 1998. The FAA has issued draft notices to airmen (NOTAMs) informing airspace users of this. JCAB has similar plans for the central Pacific. The current plan calls for RNP-10 to be implemented between flight levels 290 and 410. On 24 January 1997, the FAA issued Order 8400.12, *Required Navigation Performance 10 (RNP-10) Operational Approval*. The JCAB approval process is still being developed but is expected to parallel 8400.12. Certification to RNP-10 is required for access to reduced-separation (50 nmi) oceanic tracks.

This reduction of aircraft separations in oceanic airspace from 100 to 50 nmi is one of the principal benefits of FANS-1. The FAA's proposed amendment to the ICAO Regional Supplementary Procedures (Doc. 7030) to support 50-nmi lateral separations was submitted to ICAO in January 1995. In the summer of 1996, at the ninth meeting of the RGCSP, 50-nmi lateral separation was included in the amendment to Annex 11 (the SARPs for ATS), thus authorizing use of 50-nmi spacing between RNP-10 routes.

IPACG is also planning to implement RVSM in the north and central Pacific on 24 February 2000. The focus of Pacific RVSM is on eliminating daily crossing track problems and enabling 1,000-foot step climbs rather than on increasing airspace capacity, as was the case in the north Atlantic. This is an area where strong DoD participation in the process could result in a time-phased implementation to minimize the impact for noncompliant aircraft.

RNP-4 is the navigation element of the IPACG CNS strategy for oceanic airspace in 2003. The draft documentation submitted to begin the approval process for further reduction of oceanic separations to 30 nmi calls for an RNP-4 capability. It is expected that RNP-4 will call for full compliance with the RNP MASPS (RTCA DO-236).

2.2.3 Surveillance Requirements

ADS is the surveillance element of the IPACG CNS strategy. ADS is expected to be supported using the same datalink communications equipment that supports the CPDLC application discussed above. The reference here is to ADS-addressed (ADS-A), not ADS-broadcast (ADS-B), which is line-of-sight and will likely be supported via Mode S (Select) and/or VHF.

The initial *Operational Concept for Managing CNS/ATM Equipped Aircraft in the North and Central Pacific*, included as an attachment to the meeting summary for IPACG/9, also lists Traffic Alert and Collision Avoidance System (TCAS) situation display of aircraft as a possible additional capability for the North and Central Pacific, though no explicit plan for a TCAS requirement is stated. TCAS is currently used to support in-trail climb and descent procedures in the Oakland and Anchorage flight information regions.

2.2.4 Summary of Timeline for CNS/ATM Implementation in the Pacific

The plans for CNS/ATM implementation in the Pacific are summarized in Table 1.

Table 1. Pacific Regional Plans Summary

<i>Date</i>	<i>System</i>
April 1996	CPDLC at Anchorage center
May 1996 December 1997	CPDLC at Oakland center (24-hour, single sector) Multisector
October 1997 (trials) April 1998 (oper)	CPDLC and ADS at Tokyo center
23 April 1998	RNP-10 in North Pacific
Mid-1999	ADS at Oakland center
TBD	ADS at Anchorage center
24 February 2000	RVSM on Pacific track system
2003	"CNS" capability (CPDLC, RNP-4, ADS) in dense oceanic airspace

2.3 NORTH ATLANTIC IMPLEMENTATION PLANS AND SCHEDULES

In 1965, at a North Atlantic (NAT) regional air navigation meeting, the ICAO Council established the NAT Systems Planning Group (NATSPG). The NATSPG is subdivided into a number of committees that cover various aspects of NAT airspace management. The NATSPG Implementation Management Group (IMG), established in June 1994, is responsible for planning the future management of NAT airspace. The IMG developed the NAT oceanic concept and requirements document to address oceanic CNS/ATM concepts for the period 2000–2015.

2.3.1 Communications Requirements

The basic new communications requirement for the NAT is an oceanic datalink communication system that can support the CPDLC and ADS applications. The datalink must provide direct controller-pilot communications. Although there are no plans to make CPDLC and ADS mandatory, reduced separations and benefits will be offered only to compliant aircraft. As in the Pacific, it is expected that dual independent datalinks (a primary and a backup system) eventually will be required for access to reduced-separation oceanic tracks and in-flight rerouting procedures. Inmarsat is already approved for use as a beyond-line-of-sight primary ATC datalink. HFDFL is also under consideration as a primary and/or secondary ATC datalink in the NAT.

The ADS and CPDLC applications defined in the ICAO SARPs for the CNS/ATM-1 package are intended for use with the Aeronautical Telecommunications Network (ATN), which is ICAO's planned communications infrastructure for aviation. The ADS and CPDLC applications defined in the ICAO SARPs are significantly different from the ADS and CPDLC applications implemented in FANS-1 system that uses the ACARS infrastructure. Several transition strategies have been proposed to allow FANS-1 and ATN systems to exist simultaneously. The ICAO ADS Panel is now investigating the question of how to transition from FANS-1 to CNS/ATM-1 (ICAO SARPs-compliant) applications.

The enabling technology to support datalink applications in the NAT using the ATN is the ATN router. ATN Systems Inc. (ATNSI), an airline consortium in a cooperative agreement with the FAA, was established to implement ATN hardware and software. ATN routers will be needed on the aircraft and at ground ATC facilities to support datalink communications over the ATN. On 1 July 1997, ATNSI issued a contract to a team of vendors led by ARINC for the Conformance Test Suite for compliance testing of ATN software in avionics and ground components. The Conformance Test Suite is scheduled for mid-1999 delivery. On 15 July 1997, ATNSI contracted with Aeronautical Communication International (comprising Allied Signal, Honeywell, Sextant Avionique, Sofreavia, and Thomson-CSF) for the Router Reference Implementation, composed of avionics and ground products for routing and operation of data communications services over the ATN, including VHF, satellite, and HF subnetworks. The Router Reference Implementation is likewise scheduled for mid-1999 delivery. Aeronautical Communication International will develop ground application service elements as an FAA option but will not develop any airborne application service elements under the ATNSI contract.

The NATSPG is also considering the requirement for direct controller-pilot voice communications for emergency and nonroutine modes on reduced-separation oceanic tracks. If direct controller-pilot voice communications are required, HF voice will not be allowed under FAA rules, since it is not direct to the controller; the only system approved for direct pilot-to-controller voice communication is Inmarsat Aero. The NATSPG is beginning a safety assessment study that will evaluate these issues. The results are expected early in 1998.

2.3.2 Navigation Requirements

Today, when operating in North Atlantic minimum navigation performance specifications (MNPS) airspace, aircraft must comply with the equipage requirements defined in FAR section 91.705 and Appendix C to FAR Part 91. NAT MNPS airspace is the volume of airspace between flight levels (FL) 285 and 420 extending between latitude 27° N and the North Pole. Its eastern and western boundaries are those of the included oceanic control areas: Santa Maria, Shanwick, Reykjavik, Gander, and New York. The area west of 60° W and south of 38.5° N (roughly, the coastal U.S. from Philadelphia south) is excluded. The required navigation system performance for NAT MNPS airspace is equivalent to RNP-12.6.

The FAR has recently been amended to include requirements for reduced vertical separations in NAT MNPS airspace. The first phase of RVSM began on 27 March 1997, reducing vertical separations from 2,000 feet to 1,000 between FLs 330 and 370. State-of-registry approval is now required to operate in that airspace; unapproved operators are being excluded from FLs 330, 340, 350, 360, and 370. In December 1997 the NATSPG IMG recommended expansion of RSVM to all flight levels from 310 through 390 and has approved 8 October 1998 as the implementation date. Unapproved

operators are limited to flight levels below 290 or above 410. Further expansion of RSVN in the NAT is tentatively tied to the implementation over continental Europe in November 2001.

The NATSPG plan also calls for reductions in horizontal (longitudinal and lateral) separation. The plan is for longitudinal separation of crossing traffic to be reduced from the current 15 minutes to 10 minutes and for the in-trail separation to be reduced from the current 10 minutes to 7 minutes. These reductions will require ADS and CPDLC applications, as well as, possibly, a tighter MNPS specification. Since none of the North Atlantic oceanic centers will have ADS or CPDLC capability by 1998, reduced separations based on those capabilities clearly will not be implemented by that time. Subsequent dates for planned reductions in lateral separation in the NAT from 60 to 30 nmi will almost certainly slip as well, so they are not presented here.

2.3.3 Surveillance Requirements

As in the Pacific, ADS is the surveillance capability that is expected to be required for reduced horizontal separation in the NAT. The ADS requirements are defined in the ICAO *Manual of ATS Data Link Applications*. ADS will probably be supported with the same communications equipment that supports CPDLC.

In addition, the possible use of TCAS for increased situational awareness (SA) in oceanic airspace is being considered for the NAT. Although NATSPG has not conclusively determined whether TCAS will be a requirement for transoceanic operation in the North Atlantic, the potential for mandatory carriage was raised by the NAT IMG in its *Future Oceanic Concepts Final Report*, dated June 1995. The report expressed concern over gross navigational errors in the airspace and discussed the prospective utility of TCAS for separation assurance.

2.3.4 Summary of Timeline for CNS/ATM Implementation in the North Atlantic

The planned timeline for CNS/ATM implementation in the North Atlantic is summarized in Table 2. NATSPG documents discuss plans for reduced horizontal separations, but those planning dates cannot be viewed as reliable because of the status of ATN router development and ground system implementation at the oceanic centers. The UK has thus far been committed to implementing oceanic datalink rather than ATN and opposed to the FANS-1 "interim solution." The FAA, on the other hand, plans to implement FANS-1 at its New York center and has no plans or funding to install ATN routers at New York (or any other oceanic center). Very little has been heard about NAVCANADA's plans to date, although the panel has recently learned it will implement FANS-1 at its oceanic centers around 2000. The lack of agreement between the two sides of the Atlantic on which approach to follow (FANS-1 or CNS/ATM-1) is one of the major factors delaying datalink implementation in the NAT.

Some industry representatives have conjectured that NAT users may get most of what they want from RVSM, so airline pressure for the additional benefits provided by datalink may be small. It is highly unlikely that any datalink applications or reduced horizontal separation standards based on them will be implemented in the NAT before 2000. There is still time for DoD to influence the development of CNS/ATM requirements in the NAT, and this should be done through participation in the NATSPG via the interagency coordination process.

Table 2. North Atlantic Regional Plans Summary

<i>Date</i>	<i>System</i>
March 1997	RVSM, FL 330 to 370
October 1998	Expansion of RVSM to additional flight levels

2.4 CONUS IMPLEMENTATION PLANS AND SCHEDULES

Version 3.0 of the FAA's NAS architecture document has been published and is in coordination to correct its deficiencies and reflect FY99 appropriations shortfalls. The NAS architecture includes a summary of the FAA's planned future CNS architecture and the associated avionics equipment requirements. The document is explicit in stating that the architecture it presents is indeed a proposal and will be revised based on comments from the aviation community and other interested parties. Thus it cannot be viewed as documentation of hard requirements.

The key elements of the proposed NAS architecture with regard to CNS systems are next-generation air-ground communications (NEXCOM), transition from use of ground NAVAIDs to use of GPS for en route navigation and landing, and transition of some secondary surveillance functions from ground radars to a "cooperative-dependent" surveillance system, that is, ADS-B. These changes are intended to promote the transition to free flight. Version 2.0 of the NAS architecture prescribes a gradual implementation of these new systems, with transition completed around 2012–2014. In February 1997, the White House Commission on Aviation Safety and Security (better known as the Gore Commission) recommended that this date be pushed forward to 2005. However, this is unlikely because of the lack of funding to implement the required ground infrastructure. An additional concern is that Version 3.0 may not be executable because of budget shortfalls.

2.4.1 Communication Requirements

Until 1995 there was strong support within the FAA for VHF digital link (VDL) Mode 3 time-division multiple access (TDMA) as the next-generation air-ground communication system for the NAS. However, more recently the FAA appears to be considering other alternatives, including VDL Mode 2, aviation VHF packet communications (AVPAC). Version 2.0 of the NAS architecture document noted that NEXCOM radios could be software-programmable so that they could perform "any of the possible modulation techniques." The panel was told that Version 3.0 identifies VDL Modes 2 and 3 for air-ground communications, with a gradual transition from Mode 2 to Mode 3 if and when the FAA gets the Mode 3 infrastructure in place.

The FAA investment analysis report for the NEXCOM program was approved at the FAA Joint Resources Council. It remains in draft due to minor ongoing revisions not affecting the main thrust and validity of the analysis, which supports implementation of digital VHF radio capability in the high and super-high enroute sectors, with a transition period of 2005 through 2008. Transition to additional airspace and altitude levels will occur sometime later. The analysis supports the FAA plan to maintain existing 25-kHz analog radios and procure a limited number of analog radios as needed to maintain the system until transition to NEXCOM.

The FAA's aeronautical datalink program office is conducting a separate investment analysis ways of providing datalink services in the NAS under the so-called NOW applications program.

The Controller-Pilot Communications (CPC) program, proposed by the FAA and supported by at least one airline, plans to introduce datalink services in the NAS en route environment basically by adding a few new messages to existing ACARS management units to automate the process of transfer of control of an aircraft from one en route center to the next, anticipating that this process will develop procedures for, experience with, and confidence in using datalink for ATC in “bite-size pieces.”

The CPC proposal has stirred up considerable controversy in civil aviation. The concern CPC addresses is a valid one: introduction of datalink instead of voice for ATC brings with it a number of human-factors issues that are only beginning to be addressed, even for the oceanic environment. However, CPC is not compatible with either FANS-1 or CNS/ATM-1. It has been estimated that implementing CPC could delay CNS/ATM-1 implementation by at least 3 years. Thus ATN advocates are opposed to CPC implementation, as are supporters of FANS-1. Nevertheless, the FAA plans to continue pursuing CPC as an interim solution. A major risk area for CPC is certification; FAA/ANM-107 has stated that CPC is not certifiable in its present form.

2.4.2 Navigation Requirements

The FAA NAS plan calls for a transition from use of ground-based NAVAIDs and precision landing systems to use of GPS for—eventually—all phases of flight down to category (CAT) II and III landings. Currently, GPS is approved only for en route and oceanic navigation. The FAA has issued TSO-C129a, *Airborne Supplemental Navigation Equipment Using the Global Positioning System*, 22 February 1996, which states the requirements for aircraft to use GPS as a supplemental means of en route navigation. FAA Notice 8110.60, dated 4 December 1995, provides guidance on *GPS as a Primary Means of Navigation for Oceanic/Remote Operations*.

The FAA intends to incorporate GPS-based navigation in the NAS through implementation of the wide-area augmentation system (WAAS), a differential GPS. WAAS is intended to allow GPS to meet performance requirements for all phases of flight up to CAT I landings. The FAA expects that the final WAAS MOPS will be completed in spring 1998 and that WAAS-capable receivers will be commercially available in spring 1999. The FAA expects to issue a notice of public policy on turning off ground NAVAIDs when the WAAS achieves initial operating capability (IOC), planned for December 1998. Full operating capability (FOC) is planned for 2001. Preparation for the transition to GPS-based navigation using WAAS includes early negotiations with DoD to phase out selected ground NAVAIDs in a systematic fashion, as outlined in the Federal Radionavigation Plan (FRP). The FAA plan calls for WAAS to be approved as the primary means CAT I landings in 1998 and as the sole means for CAT I landings in 2001.

Additional augmentation will be needed to achieve CAT II and III precision-approach capability using GPS. The FAA is now defining the requirements for the local-area augmentation system (LAAS); it expects that MOPS and a specification will be published around mid-1999. LAAS IOC is tentatively planned for 2001, with FOC in 2005, if program funding is approved. As ground NAVAIDs and landing systems are turned off, NAS airspace users will need to transition to GPS navigation and landing capabilities, including WAAS and eventually LAAS augmentation. The NAS architecture calls for all the FAA’s ground NAVAIDs—including CAT I instrument landing systems (ILSs)—to be decommissioned by 2008 and for CAT II and III ILS to be decommissioned by 2010.

The FAA has also stated a 2001 date for RVSM implementation in the NAS but does not have an active program in place to meet that date.

2.4.3 Surveillance Requirements

The military is exempt from the U.S. civil Mode S and TCAS equipage requirements defined in the FAR. Passenger- and troop-carrying military aircraft, however, have been mandated to install TCAS (which requires a Level 2 or higher Mode S transponder) under the DoD Nav/Safety program.

The proposed NAS architecture calls for the deployment of ADS-B air-to-ground surveillance systems in the NAS in 2008 to 2012. The plan calls for secondary surveillance radar (SSR) systems to be decommissioned in 2014. To meet this schedule, the FAA expects to complete standards for ADS-B and the associated application, cockpit display of traffic information (CDTI), between 1997 and 2000. The ADS-B implementation now being pursued in the U.S. is based on the Mode S GPS-squitter approach. An FAA spokesman claims that there is no spectrum available to do ADS-B at VHF until NAVAIDs are decommissioned. (Europe, however, is looking at an ADS-B implementation based on the VHF Swedish TDMA scheme, discussed below.)

2.4.4 Summary of Timeline for CNS/ATM Implementation in CONUS

The FAA plans for CNS/ATM implementation in the NAS are summarized in Table 3. DoD needs to participate in the development of Version 3.0 of the NAS architecture and to ensure that the cost impact to DoD is represented in the FAA's decisionmaking process.

Table 3. CONUS Regional Plans Summary

<i>Date</i>	<i>System</i>
1998	WAAS IOC
2000–2001	Flight 2000 demo in Alaska and Hawaii (currently unfunded)
2001	WAAS FOC
2004–2010	Transition to NEXCOM
2008	All ground NAVAIDs and CAT I ILS decommissioned (transition to GPS)
2008–2012	Deployment of ADS-B
2010	Decommissioning of CAT II and III ILS
2014	Decommissioning of secondary radars

2.5 EUROPEAN IMPLEMENTATION PLANS AND SCHEDULES

The two MNCs have issued a *Statement on the Implications of Civil Aviation Developments on Military Operations*, dated 5 September 1996. This letter has been forwarded by the Chief of Staff of the Supreme Headquarters of the Allied Powers in Europe to the Chairman of the NATO Committee for European Airspace Coordination (CEAC). The positions stated in this letter are briefly summarized in the appropriate subsections below.

2.5.1 Communications Requirements

Although ICAO has endorsed TDMA as the long-term solution to VHF frequency congestion and air-ground datalink requirements, Europe has no plans for TDMA implementation and is pursuing instead a hybrid air-ground solution based on 8.33-kHz analog VHF voice and is investigating multiple air-ground datalink alternatives.

2.5.1.1 VHF Voice Operation at 8.33-kHz Spacing

The requirement to operate VHF radios at the reduced 8.33-kHz channel spacing in the upper airspace of central Europe starts in 1999. The European Air Navigation Planning Group (EANPG) approved the *Eurocontrol Plan for the 8.33-kHz Channel Spacing Implementation in Europe* on 2 December 1996. (Eurocontrol is the 24-member European Organization for the Safety of Air Navigation.) The Eurocontrol “8.33 User Guide” was approved on 21 May 1997. The date of mandatory carriage is 1 January 1999. Dual radios capable of 8.33-kHz are required, and the aircraft’s 8.33 equipage status must be indicated in the filed flight plan. The states that will implement 8.33-kHz channel spacing are Austria, Belgium, France, Germany, Luxembourg, the Netherlands, Sweden, and the United Kingdom. The general European requirement applies above flight level 245; in France the floor is set at FL 195. Noncompliant aircraft will be excluded from the airspace of mandatory carriage unless they obtain exemptions.

The states implementing 8.33-kHz channel spacing are expected to maintain and/or establish adequate UHF coverage and to adapt their procedures as necessary to provide ATC services to state aircraft that are not equipped with 8.33. This information is to be published in the national AIPs. However, if UHF coverage is not available, a state aircraft that is not equipped with 8.33 “must be denied entry into airspace of mandatory carriage and must be (re)cleared outside such airspace.” The User Guide states, “While UHF is expected to provide an alternative means of communication for state aircraft at least in some parts of the ICAO EUR region, it is essential that state transport aircraft which are frequent users of 8.33-kHz airspace be fitted with 8.33 capability.”

The German civil aviation authority (Deutsche Flugsicherung GmbH) issued an aeronautical information circular (AIC) in April 1996 to give airspace users advance notice that Germany intends to implement the 8.33-kHz channel spacing for all sectors of its upper airspace beginning 1 January 1999. Other civil aviation authorities (CAAs) are also developing AICs regarding 8.33-kHz implementation.

2.5.1.2 Air-Ground Datalink

At one time the European community was supporting implementation of an extended Mode S capability for air-ground datalink communications. However, the European consensus on Mode S datalink has eroded, and plans for its implementation are on hold. The Europeans appear to be hedging their bets, with plans to test multiple air-ground datalinks and no firm commitment to any. (Basic Mode S surveillance requirements have not changed significantly; see the discussion below.)

Eurocontrol has instituted the European ATM System program to carry out strategic planning for the European variant of free flight. The plan is very top-level at present, but does not call for “air-ground integration” (that is, datalink) until 2005–2012.

Current plans for Phase II of the preliminary Eurocontrol test of air-ground datalink include

- Multiple datalinks and ground infrastructures
- Self-organizing TDMA (S-TDMA) operating over the North European ADS-B Network
- VDL Modes 2 and 3 and Inmarsat operating over the ATN trials infrastructure
- FANS-1 operating over Inmarsat and the SITA (Société Internationale de Télécommunications Aéronautiques) ground network
- Mode S datalink

These trials are to be carried out from November 1997 through December 1998, with a final report issued in March 1999. Eurocontrol is also planning a VDL Mode 2 pilot implementation in mid- to late 1999.

2.5.1.3 S-TDMA

Self-organizing TDMA (S-TDMA), sometimes known as “Swedish TDMA,” was suggested several years ago by the Swedish CAA for various ATC datalink applications, particularly those combining ADS-B and differential GPS for precision-landing applications. Sweden has been conducting trials of this patented system since 1991, including demonstrations at U.S. civil airports and on AMC C-5 aircraft. Thus far, none of the published material on S-TDMA gives any numerical specification or performance measures that could be used to assess its suitability for near-real time ATS applications.

The Swedish scheme would require a GPS receiver, a communications management unit (CMU) with properly certified ATS applications, and a new digital VHF radio. The S-TDMA frame structure is not compatible with the TDMA frame structures developed by RTCA, Inc. (formerly the Radio Technical Commission for Aeronautics). The technical and operational issues involved in using S-TDMA for ATC are still being worked out. There are as yet no firm plans or schedules for implementing an S-TDMA system in Europe. However, it appears to be emerging as a likely candidate for ADS-B in Europe.

2.5.2 Navigation Requirements

Europe plans to develop the European Geostationary Navigation Overlay Service (EGNOS), an equivalent of the FAA’s WAAS, which will provide differential GPS service in European airspace. EGNOS will provide a seamless interface with the WAAS. This capability will be provided by navigation transponders on two Inmarsat 3 satellites—those covering the Indian Ocean and Atlantic Ocean East regions. EGNOS is scheduled to achieve IOC as a supplemental means of navigation in 1999 and FOC in 2002. Later generations of EGNOS will allow the system to be used as a primary means of navigation. Because GPS and the Global Navigation Satellite System are controlled by foreign states, the Europeans plan a second phase based on a navigation satellite system that is controlled by an international civil aviation authority.

2.5.2.1 Area Navigation (RNAV) Systems

A 1990 meeting of the European Civil Aviation Conference (ECAC) Transport Ministers developed a strategy that includes mandatory carriage of RNAV equipment when flying through European airspace starting in 1998. These requirements are spelled out in Eurocontrol Standard Document 003-93, Amendment 1, *Area Navigation (RNAV) Equipment Operational Requirements and Functional Requirements*, which has been adopted by the permanent commission of Eurocontrol. This standard takes into account the ATM implementation strategy approved at the 32nd meeting of EANPG in June 1990.

This standard mandates carriage of RNAV equipment approved for RNP-5 operations (basic RNAV, or BRNAV) on the entire ATS route network in the ECAC area, including RNAV standard arrival and departure routes, beginning 29 January 1998. BRNAV can be accomplished through the use of VOR/DME, DME/DME, Omega or Omega/VLF, or INS with periodic updates. Eurocontrol has also recently announced that it will approve GPS-based BRNAV.

Eurocontrol proposes that a decision on mandatory carriage of RNAV equipment meeting RNP-1 requirements (precision RNAV, or PRNAV) be made by the ECAC member states in 1998; they do not foresee implementation of RNP-1 equipment before 2005 and expect to maintain VOR and DME NAVAIDs until at least that date. In the current version of the document, the terms *BRNAV* and *PRNAV* refer to systems that meet the appropriate RNP accuracy requirements but are not in full compliance with the RNP MASPS.

The Eurocontrol standard applies to all aircraft under instrument flight rules operating as general air traffic in “appropriately designated and/or notified airspace.” The foreword to the document notes that, in compliance with the Eurocontrol convention, the term *general air traffic* excludes state aircraft when they are not operating under ICAO provisions. It also notes that tactical military aircraft are exempted from the provisions of the standard.

In mid-1995 the European Joint Aviation Authorities (JAA) developed an advisory circular (AMJ 20X-2) to provide interim guidance for airworthiness approval of navigation systems for use in European airspace designated for basic RNAV operations. Further documentation on certification of BRNAV and PRNAV systems will be issued in the future, and is expected to be based on EUROCAE ED75 and the RNP MASPS.

Germany has issued several AICs stating its intention to implement BRNAV and discussing requirements for certification and approval. In addition, Germany is evaluating certification requirements for RNP RNAV equipment; these are expected to be similar to those stated in AMJ 20X-2. A Direction Générale de l’Aviation Civile (DGAC) representative confirmed in November 1996 that BRNAV would be introduced above FL 245 throughout Europe beginning in January 1998 and could be extended to some dedicated part of the lower airspace or major terminal areas. Some conventional routes using ground NAVAIDs will be maintained and published. There is also a specific exemption for military aircraft that are restricted to operation on a limited number of conventional routes. The DGAC representative also confirmed that implementation of RNP-1 is some ways in the future, and not likely to happen before 2007.

The MNC position paper states that military aircraft normally operating as general air traffic (GAT) must be equipped for BRNAV, but notes that “it is not always possible to fit new equipment into the airframe of some small tactical aircraft.” The paper states that “special procedures allowing minimum restrictions should be provided to military aircraft occasionally operating GAT.”

2.5.2.2 Protected ILS

ICAO Annex 10 requires ILS localizer receivers to be protected from interference by VHF FM broadcast stations. The SARPs call for compliance with this requirement for new installations beginning on 1 January 1995 and for all installations beginning on 1 January 1998. While the SARPs do not specify any regional applicability, in fact the FM interference is a problem primarily in Europe, Africa, the former Soviet Union, and the Middle East, and ILS protection requirements are expected to be implemented primarily in Europe.

The UK CAA issued Airworthiness Notice No. 84, Issue 2, in October 1994, mandating the protection of VHF navigation receivers from broadcast FM interference. The UK has recently reissued this airworthiness notice to change the mandatory compliance date to 1 January 2001. The UK’s original airworthiness notice provided a limited degree of operational workaround for unequipped users; it planned to notify users of areas where interference to unprotected receivers

is known to exist and, if necessary, limit the categories of operation available to those operators. Germany has also issued NOTAMs advising airspace users of the protected ILS requirements; these NOTAMs essentially repeat the SARPs requirements. A DGAC representative stated in November 1996 that FM immunity will be mandatory in France as well, probably in 2001.

A few countries are installing or planning to install Microwave Landing System (MLS) equipment at selected sites, but there are no regulations requiring carriage of MLS equipment for civil compliance. The purpose of the MLS installations is primarily to add a CAT III landing capability or to maintain that capability where the existing ILS performance is being downgraded due to multipath, interference, or other causes. MLS will be implemented at several sites in the UK (including Heathrow and Gatwick) and at Schipol airport, Amsterdam, in the next 3 years.

2.5.2.3 RVSM

Europe plans to implement RVSM in continental airspace beginning in early 1999 with full implementation in 2000.

2.5.3 Surveillance Requirements

European surveillance requirements are based on use of Mode S and TCAS. The European Regional Supplementary Procedures (ICAO document 7030) state that, after 1 January 1999, flight management system (FMS)-equipped aircraft flying under instrument flight rule (IFR) in the European Air Navigation Region must be equipped with Level 4 Mode S transponders and that non-FMS aircraft conducting IFR flights must have Level 3 Mode S transponders. (Levels 3 and 4 add extended datalink capabilities to the basic Level 2 Mode S transponder needed to support TCAS or ADS-B.) To some extent the European Mode S requirements have been in flux over the past 2 years, and ICAO Doc. 7030 will be amended as described below. However, the requirements for a basic Mode S transponder have remained firm.

Germany has issued an AIC notifying airspace users of this requirement. England, France, and the Netherlands are in the formal process of adopting the Mode S requirement. It is anticipated that all Europe will require Mode S equipage. European countries are also adopting TCAS equipage requirements based not only on passenger capacity—as in the United States—but also on aircraft weight. In 1995 the Eurocontrol Committee of Management approved proposals to mandate carriage and operation of airborne collision avoidance system (ACAS) equipment.

In late 1996, Eurocontrol issued a specimen AIC entitled “Harmonisation of Regulations Governing Airborne SSR Equipment.” EANPG has been notified of the mandatory carriage dates stated in the specimen AIC so that it can begin the process of amending ICAO Doc. 7030. The mandatory carriage requirements given in the specimen AIC for IFR/GAT flights are:

- Level 2 Mode S transponder with downlink aircraft parameters (DAP) capability² for new aircraft, 1 January 2001
- Level 2 Mode S transponder with DAP capability for all aircraft, from 1 January 2003
- Antenna diversity required for aircraft with maximum mass > 5,700 kg or maximum cruising true airspeed > 324 km/hr, subject to airframe practicability

² DAP allows Mode S transmissions from the aircraft to carry aircraft state information to the ground Mode S sensor.

The AIC states that exemptions should be granted for IFR flights by state aircraft that operate as GAT in the affected airspace only “occasionally,” subject to availability of a Mode 3/A transponder with 4096 code capability and Mode C altitude reporting. *Occasionally* is defined as an average of 30 hours flying time per year in the airspace of mandatory Mode S carriage. Similar conditions apply to the DAP requirement. The AIC notes, however, that “it will not be possible to provide the same level of ATM service” to exempted aircraft as to compliant aircraft. Initial exemptions will be granted for no more than a 3-year period and will be reviewed periodically. States are also requested not to penalize older aircraft that do not have required avionics to extract and transmit the full set of DAP parameters.

The Eurocontrol specimen AIC also requires mandatory carriage of an ACAS in the airspace of ECAC member states. The AIC requires an ACAS system that complies with the ICAO SARPs; this translates to TCAS II with the new Version 7 logic. The schedule, which has been adopted “in principle,” is as follows:

- From 1 January 2000 for all civil fixed-wing turbine-engine aircraft having maximum takeoff mass exceeding 15,000 kg or with more than 30 passenger seats
- From 1 January 2005 for all civil fixed-wing turbine-engine aircraft having maximum takeoff mass exceeding 6,700 kg or with more than 19 passenger seats.

Although one intent of revising the Mode S and ACAS schedules was to “harmonise” them (since TCAS requires a Mode S transponder), total harmony apparently has not yet been achieved, since the Mode S and TCAS dates still do not match.

The 1996 MNC position paper states that “some participation in the Mode S programme is inevitable.” For the scope of this participation, it refers to a previous (1994) NATO position paper on Mode S, which states that some level of Mode S transponder equipage is necessary to enable military aircraft to access or penetrate the civilian route structure and terminal control areas, to facilitate safe coordination of military and civilian air traffic, and to facilitate use of civilian airfields by military aircraft. For military transport aircraft that regularly access the civil route structure, the MNCs view Mode S transponder equipage as a requirement to retain operational efficiency. For tactical aircraft, the MNC position is that waivers to the Mode S requirement will likely be acceptable in the early stages of implementation but that eventually they will have to comply to avoid operational restrictions. The MNC position paper concludes that “in order to enter the civil route structures, military aircraft that can be so fitted, will need to comply with a level of Mode S carriage that is acceptable to civilian ATC authorities, while remaining attuned to military requirements.” It also notes that Mode S functions must be, as a minimum, on/off-selectable from the cockpit or the appropriate aircrew station.

2.5.4 Summary of Timeline for CNS/ATM Implementation in Europe

The planned timeline for CNS/ATM implementation in Europe is summarized in Table 4.

Table 4. European Regional Plans Summary

<i>Date</i>	<i>System</i>
1 January 1998	Protected ILS receiver (ICAO SARPs date)
23 April 1998	BRNAV (RNP-5 RNAV)
1 January 1999	8.33-kHz VHF voice
1 January 2000	ACAS for all civil fixed-wing turbine-engine aircraft having maximum takeoff mass exceeding 15,000 kg or with more than 30 passenger seats
1 January 2001	Protected ILS receiver (UK airworthiness notice date) Level 2 Mode S transponder with DAP capability, for new aircraft
2001	RVSM (a limited trial is planned for November 1999, an operational evaluation in October 2000, and full implementation in November 2001)
1 January 2003	Level 2 Mode S transponder with DAP capability, for all aircraft
1 January 2005	ACAS for all civil fixed-wing turbine-engine aircraft having maximum takeoff mass exceeding 6,700 kg or with more than 19 passenger seats.
2005 or later	PRNAV (RNP-1 RNAV)

2.6 OTHER REGIONAL AND NATIONAL PLANS AND SCHEDULES

The FANS-1 implementation of CNS/ATM is spreading beyond its initial application in the South Pacific. IPACG is implementing FANS-1 in the North and Central Pacific. Other areas, mostly in Asia, the Pacific Rim, and the Indian Ocean region, are also beginning to implement new automated CNS/ATM systems using FANS-1 technology. Several FANS-1 routes across Siberia and the Russian Far East have been tested. The big advantage of FANS-1 technology is that the ground automation systems are now commercially available and can be implemented fairly quickly. Reportedly, a \$10 million investment in FANS-1 infrastructure can generate \$14 million in overflight fees. Thus, countries with poor ATC infrastructure can upgrade directly to FANS-1.

2.7 MOST LIKELY CIVIL REQUIREMENTS AND TIMELINES

In many cases future requirements are still evolving. This lack of stability in the end-state configuration imposes difficulty and risk in formulating an acquisition strategy, given the long lead time needed in the DoD acquisition cycle.

We have attempted to assess the requirements' firmness by evaluating

- standards development
- regulatory documentation
- certification criteria
- availability of compliant avionics
- level of compliance among civil air carriers
- ground system implementation status

In this process it became clear that some requirements are far better defined and further along the path to implementation than others. Our assessment is summarized in the following

subsections. Table 5 describes the civil requirements and timelines. These requirements can be generally divided into three categories: near-term (1997 to 2000), midterm (2000 to 2005), and far-term (beyond 2005).

Table 5. Civil Requirements and Timelines

Requirement	Planning Documents	Technical Documents	Carriage Documents	Dates/Confidence
8.33-kHz VHF	ICAO COM/DIV— Apr 95 MNC Statement	SARPs Annex 10 EUROCAE MOPS ED23B RTCA MOPS, DO-186A	Eurocontrol 8.33 Implementation Plan, 8.33-kHz User Guide AIC IFR 6/96 (Ger)	Eur—Jan 99 (High)
VHF DL ACARS, Mode 2 (AVPAC), Mode 3 (TDMA)	ICAO COM/DIV— Apr 95 NAS Arch Plan	Draft VDL SARPs ARINC 716-9, 750-1 TDMA draft MASPS Mode 2 draft MOPS		CONUS TDMA— 2004–2010 (Low) Europe Mode 2 ~2005 (Low)
HFDL	ICAO AMCP/ 4 Mar 96	Draft SARPs, to be completed late 97 ARINC 753, 635, 634 Draft MASPS and MOPS, to be completed late 97		Pacific 2003–2005 (Med-High) NAT >2000 (Low-Med)
SATCOM	ATS SR&O IPACG/9 FAA/JCAB Strategic Oceanic Plan	AMSS SARPs, Annex 10 ARINC Char 741 RTCA DO-210C, 215A, 222 FAA Notice N8110.58	ICAO Annex 11 proposal	Pacific 2003–2005 (Med-High) NAT >2000 (Low-Med)
CMU	All ADS/CPDLC Plans	ARINC Char 758 ARINC Report 660		
CPDLC	IPACG/9 FAA/JCAB FAA Strategic Oceanic Plan	Boeing ATS SR&O ICAO Manual of ATS DL Applications MOPS, DO-219 ARINC Char 622-2		Pacific—2003– 2005 (Med-High) NAT>2000 (Low-Med))
ADS-A (oceanic/ remote)	IPACG/9 FAA/JCAB FAA Strategic Oceanic Plan NAT NOCAR	Boeing ATS SR&O ICAO Manual of ATS DL Applications MOPS, DO-212 ARINC Char 745, 622-2		Pacific—2003 (Med-High) NAT>2000 (Low)
ADS-B	NAS Arch Plan	ARINC Char 718, Supp. 5 (draft) SC-186 MASPS, mature draft		CONUS— 2008–2012 (Med)

Table 5, cont. Civil Requirements and Timelines

Requirement	Planning Documents	Technical Documents	Carriage Documents	Dates/Confidence
RVSM	IPACG RVSM Task Force 1 FAA Strategic Oceanic Plan NAT NOCAR	ICAO SARPs, validation stage FAA Notice 91—RVSM	FAA AIC 80/9096 (Yellow 226) FAR Part 91	NAT FL 330-370—Mar 97 NAT FL 290-410—2000 (50+%) Pac 2000 (High) Eur 2001 (Med/High) CONUS 2001 (Low-Med)
RNP-10	FAA Draft NOTAMs ICAO RNP Manual FAA Strategic Oceanic Plan IPACG/9	MASPS, DO-236 FAA Notice 8110.60 FAA Order 8400.12		NOPAC—Apr 98 (High)
RNP-5 (BRNAV)	Ger AIC 21/95	Eurocontrol Std Doc. 003-93 JAA AMJ-20X-2	Ger AIC IFR 5/96 Eurocontrol Std Doc. 003-93	Eur—23 Apr 98
RNP-4	ICAO RNP Manual IPACG/9 FAA/JCAB NAT NOCAR	MASPS, DO-236 TSO-C129A/8110.60 Boeing RNP for FANS-1		Pacific—2003 (Med-High) NAT >2000 (Low)
RNP-1	ICAO RNP Manual	MASPS, DO-236		Eur—2005 (Med)
P-ILS	ICAO COM/DIV—Apr 95	SARPs, Annex 10 MOPS, DO-195, 196, 186	UK CAA Airworthiness Notice No. 84 Ger NfL II 68/94 Ger NfL 75/96	Eur—2001 (High)
GPS Landing	NAS Arch Plan FRP	MASPS, RTCA DO-217 MOPS, DO-229 (WAAS)		CONUS WAAS—2001 (Low-Med) LAAS >2001 (Low-Med)
TCAS	NAT IMG Future Oceanic Concepts IPACG/9	SARPs, Annex 10, Vol 4 ARINC 735-2 MOPS, RTCA DO-185	Eurocontrol Specimen AIC, late 96 Swed AIC 8/1996	Eur—2000, 15,000+ kg, or 30+ seats Eur—2005, 5,700+ kg, 10+ seats (High)
Mode S	NATO Position Papers Eurocontrol Mode S CONOPS	SARPs Annex 10 MOPS, RTCA DO-218, 181A ICAO Manual on Mode S	ICAO Doc. 7030 Ger AIC 13/92 Eurocontrol Specimen AIC, late 96	Eur—Level 2/DAP New a/c 2001 All a/c 2003 (High) Extended DL cap. Date TBD (Low)

2.7.1 Near-Term Requirements (1998–2000)

The near-term requirements are the firmest. They include European requirements for 8.33-kHz VHF voice, protected ILS, BRNAV, and the Pacific requirement for RNP-10.

The need to operate VHF radios with 8.33-kHz channel spacing in the upper airspace of central Europe starting in 1999 is the only hard VHF requirement that has arisen thus far. SARPs for 8.33-kHz have been adopted; the implementation plan has been approved by EANPG; European nations are beginning to issue AICs regarding 8.33-kHz avionics equipage and to upgrade their ground VHF infrastructure; vendors are offering compliant equipment; and airlines are equipping their European fleets. The MNC position paper recognizes that U.S. military aircraft that frequently use the core European airspace will need to be equipped with 8.33-kHz radios, though NATO continues to pursue workarounds based on UHF coverage for aircraft that cannot comply or require only infrequent access to the affected airspace.

The requirement for protection of ILS systems from FM interference in European airspace is similarly firm. SARPs have been adopted and several European CAAs have issued AICs or airworthiness notices regarding avionics compliance. While the implementation date stated in the SARPs (1 January 1998) will slip somewhat in some countries, the intent to implement the requirement is clear. Replacement avionics and mod kits for existing avionics are widely available, and airlines are upgrading their ILS receivers.

The requirement for a BRNAV capability for IFR operation in European airspace beginning 1 January 1998 is also firm. Carriage of area navigation equipment approved to RNP-5 is mandated in a Eurocontrol Standard document that has been adopted by the permanent Eurocontrol commission. The JAA have issued guidance material for airworthiness approval of BRNAV systems; Germany has issued an AIC on BRNAV implementation and is evaluating certification requirements. Some exemptions for military aircraft (particularly tactical aircraft) are expected, but the NATO MNC position paper recognizes the need for military aircraft that normally operate as general air traffic to comply with BRNAV requirements.

RNP-10 above FL 280 was implemented in the Pacific and over the Tasman Sea on 23 April 1998. Since there is no ground infrastructure development needed to support RNP-10 operations, the actual implementation date will depend on the rate at which airspace users are able to certify their aircraft. The FAA has issued guidance material on airworthiness and operational approval requirements for RNP-10 operation and is working with aircraft operators, including AMC, to help with and monitor their progress in achieving RNP-10 approval. The April 1998 date appears achievable and fairly firm.

2.7.2 Midterm Requirements (2000–2005)

Midterm requirements include European plans for mandatory carriage of Mode S and TCAS equipment and Pacific regional plans for requiring a “CNS” capability in dense oceanic airspace by 2003. The panel’s assessment is that these requirements are fairly firm, although implementation dates may well slip. Plans for ATN implementation in the North Atlantic also fall within this time period; however, we view these implementation dates as less firm than those for the Pacific because of the current status of ATN router and applications development.

Eurocontrol’s most recent specimen AIC summarizes Mode S and TCAS carriage requirements. EANPG has been notified of the mandatory carriage dates stated in the specimen AIC so that it can begin amending ICAO Doc. 7030. The AIC calls for new aircraft to carry a Level 2 Mode S

transponder with DAP capability by 1 January 2001, and all aircraft by 1 January 2003. Exemptions will be granted for IFR flights by state aircraft that operate as GAT in the affected airspace only occasionally, defined as an average of less than 30 flight hours a year, at the price of a reduced level of ATC service. Initial exemptions will be granted for no more than a 3-year period and will be reviewed periodically. The AIC also mandates carriage of a SARPs-compliant airborne collision avoidance system (TCAS II with change 7) in the airspace of ECAC member states for civil fixed-wing aircraft by 2000 or 2005, depending on aircraft size and/or passenger capacity.

The MNC position paper recognizes that some level of Mode S transponder equipage will be necessary for military aircraft operating in Europe, particularly transport aircraft that regularly access the civil route structure. For tactical aircraft, the MNC position is that waivers to the Mode S requirement will likely be acceptable in the early stages of implementation but that eventually they will have to comply with the requirement to avoid operational restrictions. Although European TCAS requirements do not apply to military aircraft, TCAS equipage is mandated as part of the Nav/Safety program.

Our assessment is that the European requirements for carriage of TCAS equipment and the basic Mode S transponder capability needed to support TCAS operation will likely come to fruition in the midterm.

Regional plans for the Pacific, which have been agreed to in principle by the FAA and the JCAB (the primary providers of ATS in the North and Central Pacific) call for mandating a CNS capability (RNP-4, ADS, and CPDLC) in dense Pacific oceanic airspace by 2003 to support reduction of separations to 30 nmi. This implies a requirement for integrated GPS navigation and for an oceanic datalink capability to support the ATS applications. These are essentially the functions provided by the FANS-1 package.

Dual independent datalinks are likely to be required eventually to provide the expected system availability and redundancy requirements for 30-nmi separations. Because of the expense of dual satcom equipage and the strong industry push for HFDDL approval, we expect that a satcom/HFDDL configuration will be acceptable. The jury is still out on acceptability of dual HFDDL equipage, though HFDDL advocates at ARINC and the FAA do expect approval. Given that the planned CNS implementation is based on FANS-1 and thus uses the existing ACARS/Aircom communications infrastructure and commercially available ground automation equipment, the 2003 date seems feasible for implementation, although the date for mandating CNS equipage in the Pacific may slip depending on the rate of airline equipage.

The requirement for a satellite voice link for direct pilot-controller communications as a backup to the datalink systems has been a contentious issue for some years now and is expected to remain so. The international controllers' union has been insisting for at least 2 years that they do not believe 30-nmi separations in the Pacific will be safe without direct pilot-controller voice, and this position now has some advocacy within ICAO (at the ADSP) as well. A corollary consideration is that many passenger airlines that fly oceanic routes are equipping with voice-capable satcom equipment anyway for passenger use, and thus there might not be strong airline resistance to such a requirement. Our assessment is that the satellite voice requirement is not likely to go away, though in the future other systems than Inmarsat might be used.

Plans for the North Atlantic call for essentially the same capabilities as those needed for the Pacific (ADS, CPDLC, and RNP-4). The lack of agreement across the Atlantic on which approach to follow (FANS-1 or CNS/ATM-1) in implementing the CPDLC and ADS datalink applications is

one of the major factors delaying datalink implementation in the NAT. Delays in ground system implementation and in awarding the ATNSI router contract to develop the ATN router software have rendered NATSPG planning dates unreliable.

Some industry representatives have conjectured that NAT users may get most of what they want in terms of increased airspace capacity from RVSM, so the airline pressure for the additional benefits provided by datalink may be small. Given the current schedules for ATNSI product development and CAA implementation, we consider it unlikely that any datalink applications will be implemented in the NAT before 2000. We would not expect any reductions in aircraft horizontal separations to be approved until some time after that.

2.7.3 Far-Term Requirements (Beyond 2005)

The requirements and implementation schedules are still evolving for the far-term systems, in which category we include European plans for air-ground datalink and U.S. plans for next-generation air-ground radios, ADS-B, and GPS-based area navigation and landing systems. In general, we believe that widespread introduction of air-ground ATC datalink in the en route and terminal environments will not be fast. First, there is not an industry consensus on which datalinks will be used or what applications/services will be provided. Second, the human factors issues associated with using ATC datalinks in those environments are significant, and are only beginning to be addressed.

Eurocontrol's strategic ATM plan, intended to lead to the European variant of free flight, is very top-level at present, but does not call for datalink implementation until 2005–2012. The type of datalink has, thus far, been left vague because of its political sensitivity. Current European plans call for multiple datalink and ground infrastructure tests to be carried out between November 1997 and December 1998, with a final report to be issued in March 1999. Eurocontrol is also planning a VDL Mode 2 pilot implementation in mid- to late 1999. A Eurocontrol spokesman recently said that if he had to place a bet, it would be on VDL Mode 2.

Although implementation of some of its provisions will begin in the near term, the panel considers the FAA's NAS architecture (NEXCOM, GPS navigation, and ADS-B) to fall into the far-term category because of the planned long transition period. The NAS architecture is designed to promote a gradual transition to free flight through the year 2010 or beyond. We do not consider the accelerated 2005 date recommended by the Gore Commission to be achievable; the FAA has stated as much, based on funding considerations. We also expect that NAS architecture plans may change based on the outcome of the planned Flight 2000 demonstration. The Mode S squitter ADS-B concept appears to have some advocacy in U.S. civil aviation, so it may see limited implementation sooner than 2010, though the panel's guess is that it would not be mandated right away. Because these dates are so far in the future, the system requirements and operational concepts are still being defined, and the NAS architecture itself still being revised, our assessment is that it is too soon to make equipment decisions on these capabilities. This is a test of the system!

Chapter 3—Capabilities vs. Equipment

3.1 INTRODUCTION

The Air Force, as well as other DoD airspace users, shares many (but not all) of the same information exchange requirements (IERs) as civil aviation in its need for safe and efficient global access. Increasing airspace capacity, providing better SA, and offering more flexibility in route planning are items the Air Force wants. Knowing where the Air Force is with accuracy and assurance and being able to let other pertinent players know about the Air Force's location are just as clearly the prerequisites to accomplishing those items. In fact, these features are equally important in support to all military operations. Through identification of required performance and functions, the Air Force can open up important possibilities for cross-linking of information between all military systems—for example, cross-linking GPS and Link 16 information, investigating use of Link 16 messages for Mode S information requirements, using GPS for friendly identification (thereby requiring query and response) and concentrating other capabilities on unknown, pending, and hostile tracks.

A stumbling block in getting the Air Force to embrace the improvements offered by the future FAA/ICAO vision is that, in some cases, the implementation is still defined in terms of hardware/software solutions rather than required performance. This may preclude a cost-effective solution based on capabilities already on the aircraft.

What is needed is a bridge between those who require the information (for purposes of this discussion, the ATC providers) and those who hold the information (the airspace users) that would be flexible enough to include several ways to solve the information needs—from buying identical hardware and software at all locations to developing smart gateways that enable information translation among several communications media. This will require a shift in the way civil aviation authorities write their requirements. In fact, this shift is already under way, particularly in navigation, and DoD should proactively work to extend this concept to surveillance and communications performance.

3.2 CHANGING THE CULTURE

DoD is exploring the possibility of using military-specific navigation and communications means to derive the needed information and capability and then present that data to CAAs in the form they specify. The key to moving ahead on this will be to get Air Force (and other DoD airspace users) to participate in the process of defining required CNS performance and to participate in defining IERs at the message and common-data-dictionary level. The RTCA special committees are developing MASPS for RNP, RCP, and required surveillance performance (RSP). We recommended these committees as the place to begin DoD participation.

Required information content from these documents defined down to the lowest detail can be compared with existing datalink messages. Part of the challenge is to capture how the information needs to be measured and presented. Information required for CPDLC, for example, needs to be compared with message sets from Link 16 and other military datalinks. Then an analysis of how best to communicate that information to the customers can be done. Existing or modified Link 16 messages and Joint Tactical Information Distribution System (JTIDS) or Multifunction

Information Distribution System (MIDS) radios can be used to pass required location and intention information to a gateway, where the information would be translated into the form needed by the ATS community. This could relieve any requirement to put new equipment on Link 16-equipped airplanes while still providing the needed information. This gateway should be capable of two-way transmission to enable amplifying SA information to be broadcast to aircraft. (JTIDS is currently a line-of-sight system, although a future requirement for range extension—JRE—has been identified. For oceanic operations, JRE capability or augmentation with other satellite or HF capabilities will be required.)

The real power of defining information in these common terms lies in the transition to the need for a common database with shared/fused information from a variety of disparate sources that can be used by all valid users independent of media. This enables expanded friendly SA information (one primary purpose of GANS) to support battlespace users where this information is equally critical.

3.3 MILITARY DATALINKS

The Air Force has long recognized the tremendous potential of communications datalinks to improve information throughput and understanding and to enable electronic integration of data into other platform systems. Tactical Digital Information Link (TADIL) J, also known as Link 16, has been identified as the DoD primary datalink and is being procured for most Air Force platforms in the near future. The challenge is to provide some structure to ensure interoperability among datalinks of the military Services and multinational users. As we enter the datalink-requirements world of global air navigation, this challenge will become ever greater and even more essential.

ASD/C³I recognized the need for a coordinated approach to the datalink family and developed a Joint Tactical Data Link Management Plan (JTDLMP), which establishes a J-series family of tactical datalinks (including TADIL J/Link 16, Link 22—mainly a naval datalink—and variable message format—mainly used by ground forces), based on TADIL J messages and/or data elements as the initial step toward achieving the goal of allowing an interchange of messages that would be independent of specific communications media. The JTDLMP states, “A major goal of this plan is to standardize C⁴I messaging and data elements used to provide a seamless, flexible datalink environment.” This goal also clearly has relevance to global air navigation operations.

The JTDLMP and the hierarchy of message development that it describes provide an important tool to maximize joint and combined combat capability by aiming to create a seamless, interoperable data exchange environment. Realistically, though, gateways are a fact of life because of the different media used by the Services. The Air Force also knows historically that gateways can be an impediment to interoperability unless they are supported by extremely detailed data-forwarding rules and protocol documents.

3.4 GATEWAYS

A gateway approach can be used to support global air navigation requirements, both inter- and intraregion. The scenario of differing media being used by people with similar information requirements described above for strictly military users has direct applicability to the combination of military and civil ATS providers and airspace users.

The fact that gateways could be built to take advantage of existing military-specific capabilities doesn't necessarily mean that some new equipment may be put on aircraft. It does mean that the military should have the flexibility to determine which way we want to satisfy the requirement.

3.5 STANDARDIZED MESSAGE CONTENT

One major goal for future global airspace strategy must surely be worldwide standardized message and data elements. This will greatly simplify training and operations challenges while enabling simpler, cheaper gateways between different systems that are using this standard information content. In order to achieve this level of standardization, several key questions need to be asked (and answered). These questions include:

- What are the IERs between the affected players, and how will they be satisfied? IER development requires an analysis of *who needs* specific information, *who has* that specific information, *how* it can be transmitted, and *how* it needs to be presented to the user.
- What are the interoperability requirements between datalinks and supported systems and how will they be satisfied?
- Have the data-forwarding requirements/message translation/data-forwarding rules between the datalinks been defined?

The clear challenge will be to achieve agreement among the many military and civilian communities. ICAO is developing SARPs for these datalink applications. RTCA wrote DO-212 and 219 to specify ADS and CPDLC message format and content. FANS-1 implementation of ADS and CPDLC is based on DO-212 and -219, but is slightly different. The ICAO SARPs are significantly different from DO-212/219 and FANS-1. This disparity is of concern and needs to be resolved to achieve maximum benefit for all users.

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Chapter 4—The Impact of GATM Noncompliance

4.1 INTRODUCTION

It is imperative for DoD to understand the capabilities needed to operate in the future ATM environment, the associated benefits, and the impacts if it chooses to be noncompliant. Failure to equip has historically resulted in restrictions on flight operations. Preferred routes and reservations are set aside for properly equipped aircraft because it is more efficient for the ATM system to provide services to aircraft with the same capabilities in specific airspace segments and to exclude aircraft that do not comply. Those with limited capability are geographically separated (both vertically and horizontally), forced to fly nonoptimum profiles, or delayed or denied entry into specified airspace altogether. Although ICAO and civil aviation authorities cannot mandate system capability for the military, they can apply “extortion through exclusion.” This was the case in the late 1960s when military aircraft without Mode C were excluded from positive-control airspace, and again in the late 1970s when aircraft without inertial navigation systems (INS) were excluded from operating at optimum altitudes in the MNPS airspace over the North Atlantic.

With implementation of RVSM in MNPS airspace over the North Atlantic, exclusion has once again become a reality. Today, AMC KC-135 aircraft are being forced to operate outside RVSM airspace below FL 290. A study conducted by the AMC Studies and Analysis Flight (HQ AMC/XPY) determined the annual increase in fuel cost alone to be \$6.8 million. Operational Support Aircraft assigned to AMC are also being impacted by exclusion from RVSM airspace. Recently a C-21 aircraft was forced to delay its redeployment from Europe for 5 days, waiting for a waiver to operate in RVSM airspace as a result of being noncompliant. Both European and Pacific planning groups are beginning the process of implementing RVSM by 2000, increasing the range where the impact of RVSM noncompliance will be felt.

The next step is the reduction in horizontal separation through implementation of RNP standards and the eventual implementation of CNS/ATM routes. Implementation of CNS/ATM routes will require new communications and surveillance capabilities; in the near term these capabilities may be specified in terms of equipment, though a long-term goal is to specify RCP and RSP instead. RNP-10 has already been implemented on some South Pacific routes and is scheduled for implementation in the North and Central Pacific region between FLs 290 and 410 on 23 April 1998. Once again, noncompliant aircraft will be excluded. Further reduction in horizontal separation is expected to follow in 2003 with implementation of RNP-4.

The operational impact of GATM-like requirements will vary with the aircraft mission. The impact will be different for Air Force fighter aircraft than for transports, for example, and the impact on naval aircraft will not be as great as that on Air Force operations because of the differences in the CONOPS and the normal operational environment. Naval aircraft are designed to support flight operations from the sea. Specifically, naval aircraft, like Air Force tactical aircraft, must be able to get to the conflict, win the conflict, return from the conflict, and be as interoperable with our allies as possible. Resources in excess of these requirements are expended by priority to gain interoperability with the civil CNS/ATM environment.

This does not suggest that an operational benefit will not be gained by a naval investment in GATM-related technology. It does suggest that the investment decision by the Navy will not be

as time sensitive or critical as a comparable decision by the Air Force. The Navy has a planned investment strategy to install GATM-like technology in its legacy aircraft.

Specific information is lacking on future impacts of full CNS/ATM implementation to operators that do not or cannot comply. However, there are several indications once again that noncompliant aircraft will be geographically (vertically as well as horizontally) separated, that is, excluded from the airspace. Noncompliant aircraft can expect to be held on the ground and to receive longer sequencing vectors, additional holding patterns, longer routes around holding patterns, and longer routes around the most desirable airspace. The bottom line for noncompliant aircraft is that they can expect to spend more flying time in nonproductive special handling.

4.2 AIRLIFT ANALYSIS ASSUMPTIONS, MODEL, AND APPROACH

The AMC/XPY study analyzed the potential impact of GATM noncompliance based on the assumption that a GATM-noncompliant aircraft would be penalized in all regions of the globe with longer flight times. Since actual penalties have not been quantified, penalty times were varied according to an experimental design. A classified version of the impact study is available, which used Mobility Resource Study Bottom-Up Review Update major regional contingency (MRC) scenarios and assumptions.

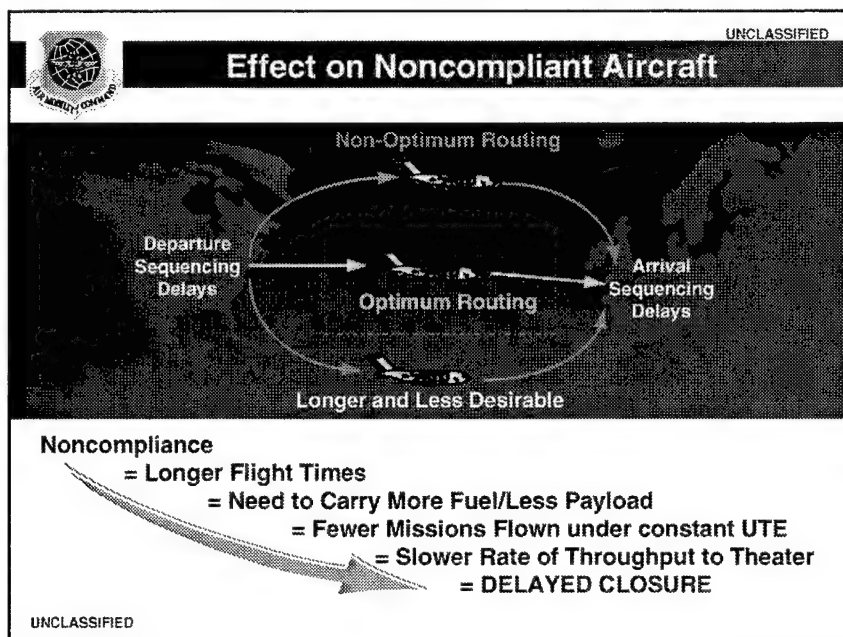


Figure 1. Effect on Noncompliant Aircraft

AMC's Mobility Airlift Support System (MASS) was used to estimate the impact on airlift capability. The simulation engine behind MASS is the Airlift Flow Model, a detailed, discrete-event simulation that plans missions deterministically and executes stochastically. During simulation execution, a random penalty was imposed on each flight. The mode (most likely) penalty was fixed for each simulation. Each flight was assumed to carry enough extra fuel to accommodate the most likely penalty, since actual flight delays were assumed to be unpredictable beforehand. This type of variation in flight times was used to impart a worst-case impact on the

scheduled airlift flow. The impact study was based on the assumption of unlimited available ground infrastructure. In reality, delays in scheduled flow of aircraft would result in ground delays exceeding the minimum on ground due to unavailability of proper material-handling equipment, aircrew staging, fuel availability, etc.

The additional fuel needed per flight displaced cargo and consumed limited ground fuel supplies at a faster rate. The impact of the additional random flight times increased the mission cycle times accordingly and made some routes unfeasible for the C-17. Though not a formal validation, these effects seem reasonable. The cumulative impact of these individual effects and their repercussions on the airlift system are significant and are described in the next section.

4.3 IMPACT ON AIRLIFT

Figure 2 shows the impact of moving a requirement the size of Desert Shield/Desert Storm with the projected airlift fleet of 2006. The military fleet was assumed to be noncompliant, but the Civil Reserve Air Fleet (CRAF) was assumed to be compliant. To understand the potential impact of noncompliance a range of 30, 60, and 90 minutes per sortie was evaluated. This range is reasonable to justify in terms of:

- Additional holding patterns (4 to 5 minutes each)
- Less favorable winds (10 to 20 minutes)
- Longer routing and sequencing (10 to 40 minutes)

Considering the potential for one to three holding patterns both on departure (5 to 15 minutes) and on arrival (5 to 15 minutes) with additional delays (20 to 60 minutes) as outlined above defined the range of 30 to 90 minutes used in this study. Additional fuel, corresponding to the expected delay, was added to each aircraft before computing the payload for each flight.

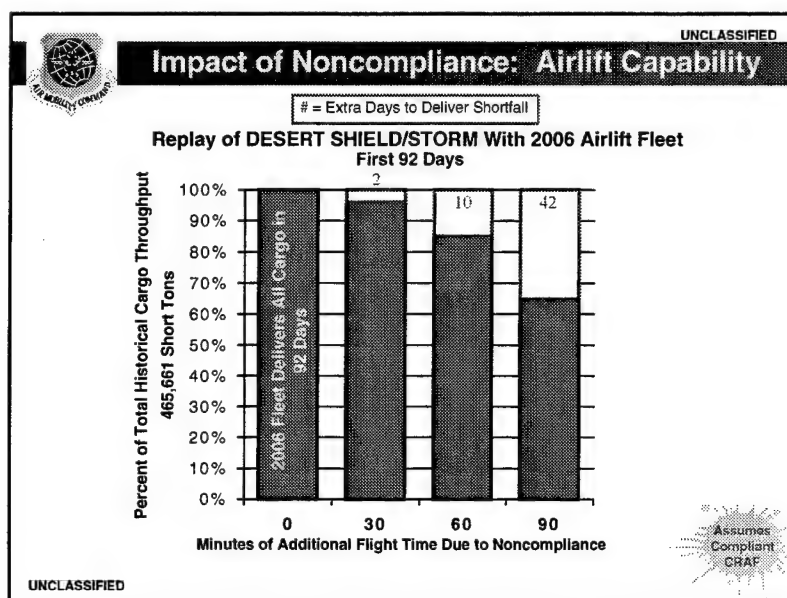


Figure 2. Impact of Noncompliance: Airlift Capability

The blue (solid) bars in Figure 2 represent the amount of cargo delivered in 92 days, which is how long it took to deliver all the cargo in the baseline scenario. The red numbers over each blue bar depict how many additional days it would take to deliver the shortfall.

The study also assessed the impact of noncompliance of a single weapon system. For example, if only C-5 aircraft were not GATM-compliant, then outsize, oversize, and bulk cargo would be impacted most. Though total cargo throughput is not as significant when considering the impact of the individual weapon systems, an analysis of the throughput for each of the subcategories of cargo (outsize, oversize, and bulk) shows that outsize cargo is immediately impacted even with a 30-minute penalty. Outsize cargo represents some of the warfighter's most critical equipment, and this immediate impact on outsize cargo is significant to the fight.

Not all of the CRAF carriers will have an immediate business incentive to upgrade their airframes to satisfy GATM requirements. In fact, the lack of GATM standards, the high cost of GATM equipment, and the ability to remain economically competitive will most likely drive CRAF participating carriers to regionalize their fleets. Since the military fleet carries almost all the outsize and oversize cargo, there would be little impact on outsize and oversize cargo capability. CRAF noncompliance specifically impacts bulk cargo and, more significant, passenger throughput. Essentially, most of the warfighting equipment would get to the fight, but there would not be enough soldiers to use it.

4.4 IMPACT ON AIR REFUELING

Like the airlift analysis, the air refueling analysis was based on the assumption that GATM-noncompliant aircraft would be penalized by extended flight times due to less desirable routing. Because we assumed some control of U.S. and theater airspace, deployment airspace was the primary focus.

The analysis was conducted using the Contingency Mating and Ranging Planning System (CMARPS), which is used by more than 18 Air Force/DoD organizations to determine tanker requirements based on receiver fuel demand. The baseline case of this study represents zero operational delay. Higher fuel reserves were then imposed to represent the penalties of 30, 60, and 90 minutes of additional flight time due to an airspace-related delay. Using the higher fuel reserves, CMARPS was used to reflow the combat force deployment to estimate the impact on deployment timelines.

The additional fuel needed per flight would require additional tanker aircraft to support some deployment movements. If no additional tankers were available, as in a dual-MRC scenario, deployment delays would result. In addition, increased flight times would result in crews' reaching their flying-hour limits at an accelerated pace. In a crew-constrained dual-MRC environment, this would result in lost missions for lack of aircrews. The cumulative impact on combat air forces due to reduced air refueling capability is described in the next section.

When 30, 60, or 90 minutes of additional fuel and flight time is required for each tanker aircraft, air refueling operations are restricted because the tanker must retain more fuel to allow for operational delays. The closure requirements can be met if tanker aircraft are GATM-compliant. However, if delays are incurred due to GATM noncompliance, the time to mission closure is extended, and combat aircraft will not be available for combat sorties. Compounding this impact is the decreased number of tankers available in theater to support combat sorties because tankers

are tied up supporting the extended deployment. The ability of airpower to contribute effectively to halting phase operations is diminished by a tanker fleet that is not GATM-compliant.

4.5 IMPACT ON BATTLESPACE MANAGEMENT

Adoption of GATM-like technology by the vast majority of the aviation community—civil and military—presents challenges for military air surveillance and especially the Navy. In the past, over-ocean flights were confined to a small number of published tracks. Blue-water flight operations could be conducted clear of these published areas with a high degree of confidence that nonparticipant interference would not be a concern. Universal acceptance of GATM-like technology might force C² platforms supporting DoD operations in uncontrolled airspace to upgrade their equipment to be able to monitor and identify this civil traffic. New communication links between the operational commander and the FAA and other CAAs might be required to exchange time-critical flight information (for example, on civil aircraft, in-flight rerouting information derived from oceanic datalink systems).

Likewise, the worldwide use of Mode S-based TCAS II equipment by both civil air carriers and military platforms could have an impact on battlespace management. Today, military C² platforms are not able to receive the automatic broadcasts (squitter) of Mode S-equipped aircraft. Significant ID information is available (with TCAS II version 7, aircraft location and intent are broadcast) and the military is not equipped to receive it. At a minimum, military C² platforms might need to be equipped with dumb Mode S terminals to provide air picture SA for the operational commander.

4.6 COMMUNICATIONS

4.6.1 8.33-kHz VHF Voice

DoD aircraft frequenting core European airspace and operating as GAT without 8.33-kHz capability will suffer altitude restrictions below FL 195 in France, and below FL 245 in Austria, Belgium, the Netherlands, Germany, Luxembourg, Switzerland, and the UK beginning 1 January 1999. DoD aircraft operating as operational aviation traffic (OAT) will be limited to UHF and OAT structure. Eurocontrol's 8.33-kHz implementation plan and user guide direct member states to provide UHF coverage to support state aircraft. ICAO is reportedly surveying member states to assess the viability of using UHF as a long-term workaround for aircraft not equipped with 8.33-kHz capability. The effects range from longer flight times and increased fuel consumption to an inability to perform certain missions or flight profiles in the affected airspace. Supreme Headquarters of the Allied Powers in Europe and NATO continue to pursue exemption from the 8.33-kHz requirement and for extended UHF coverage, but recognize the need for aircraft that frequently operate as GAT in Europe to comply.

Air Force tankers, transports, and large special-use aircraft (such as the E-3, E-4, E-8, HC-130, and R/O/TC-135) routinely operate in GAT airspace. Departure and routing restrictions would significantly impact their operations. No significant impact on other Air Force special-use platforms (the EC-130E/H, HH-60, U-2, SR-71, and YAL-1) or on bombers or fighters is expected, provided the UHF and OAT structures remain in place. Unmanned aerial vehicle (UAV) flight profiles will not normally be in GAT airspace, so no impact on their operations is expected.

The Navy CONOPS and its infrequent use of European bases suggest that the 8.33-kHz issue will not adversely impact flight operations in a measurable fashion. A significant number of aircraft in the naval fleet are being equipped with digital radios capable of 8.33-kHz spacing in addition to their military functionality. If the capability is required, an aircraft with this radio could be used.

4.6.2 Datalinks (Oceanic)

In oceanic airspace, where datalink use for communications and surveillance (CPDLC and ADS-A) is mandated to support reduced horizontal separation, noncompliance will result in denied or restricted access to that airspace; the optimum oceanic tracks will be reserved for compliant aircraft. This will result in nonoptimal routes, longer flight times, increased fuel consumption, and reduced payloads for noncompliant aircraft. In addition, aircraft that are not equipped with oceanic datalink capability will be unable to take advantage of in-flight rerouting procedures. Air Force tankers and transports, special-use platforms (except the HH-60, which does not fly transoceanic), bombers, and the Global Hawk UAV will require this capability to support a worldwide deployment capability. Fighters will fly transoceanic routes using altitude reservations with tanker support and are not expected to require oceanic datalink capability.

For the Navy, an oceanic datalink capability devoted to peacetime interoperability is in the “nice to have” category. The Navy is at home in the oceanic environment and “home plate” does not signify the need for “host-tenant” or “status of forces” agreements. Home plate is the air-capable ship the aircraft are launched from, and if coordination is required, the ship will handle it for its aircraft.

4.6.3 Datalinks (CONUS)

In the United States the plan is to continue the transition from voice to air-ground datalinks for provision of ATS. This transition began with implementation of services such as predeparture clearance (PDC) and digital air traffic information services. A number of major airlines now rely on PDC to streamline operations at their hubs. Initially the impact will be denial of ATC services and benefits that are based on air-ground datalink; eventually noncompliance in airspace where datalinks are mandatory may result in denied or restricted access to that airspace. All Air Force platforms are expected to be affected to some degree, but the impact cannot be assessed in detail until the CONOPS for air-ground datalink use is better defined.

The Navy will selectively equip its fleet as necessary to avoid airspace exclusion when the penalty for noncompliance will be detrimental to mission accomplishment. The naval CONOPS (that is, minimal airways flying, unit basing at military rather than civil airports, and proximity of special-use airspace to the home station) are factors that will mitigate the investment required. The VHF/UHF digital radios being introduced into Navy tactical aircraft provide an upgrade path to VHF air-ground datalink capability.

4.6.4 Datalinks (Europe)

Europe is also planning for an eventual transition from voice to air-ground datalinks for provision of ATS. As in CONUS, the initial impact will be denial of ATC services and benefits that are based on air-ground datalink; eventually noncompliance in airspace where datalinks are mandatory may result in denied or restricted access to that airspace. All Air Force platforms that operate in Europe, as well as some training aircraft, are expected to be affected to some degree, but the

impact cannot be assessed in detail until the CONOPS for air-ground datalink use is better defined. The Navy CONOPS and its infrequent use of European bases suggest that the impact of European air-ground datalink implementation on the Navy will not be significant. As with the CONUS datalink question, the VHF/UHF digital radios being introduced into Navy tactical aircraft provide an upgrade path to VHF air-ground datalink capability.

4.7 NAVIGATION

4.7.1 Reduced Vertical Separation Minimum

RVSM has been implemented in the North Atlantic MNPS airspace and is planned for implementation in the Pacific, Europe, and CONUS by 2000–2001. Several DoD platforms (the C-5, KC-10, C-17, VC-25, and C-141) are certified for RVSM compliance; C-20 certification is under way. As discussed above, noncompliant DoD aircraft are already being excluded from RVSM airspace. Because the affected airspace extends from 27° N latitude to the North Pole, noncompliant aircraft must fly below FL 330 or above FL 370. In practice, oceanic controllers are sometimes applying RVSM criteria to the entire MNPS airspace (beginning at 290) despite the nominal retention of workaround altitudes for noncompliant aircraft. The effects of RVSM noncompliance include longer flight times, increased fuel consumption, reduced aircraft payloads, and schedule disruptions due to an inability to obtain a crossing slot time.

This requirement affects the remaining noncompliant Air Force tanker and transport fleets (KC-135, C-9) and large Air Force special-use aircraft (E-3, E-4, E-8, O/R/TC-135); these aircraft routinely fly in the affected altitude range and will face altitude restrictions due to RVSM noncompliance, initially in the North Atlantic but eventually in the Pacific, Europe, and CONUS. RVSM requirements do not affect aircraft that can fly above the affected airspace (U-2, SR-71, Global Hawk) or typically operate below it (B-1, C-130, EC-130E/H; HC-130; HH-60). The Air Force plans to use altitude reservations for fighters and for B-2 and B-52 bombers that must fly transoceanic routes, but this will require additional coordination.

The Navy will address the RVSM issue platform by platform. It has no plans to address the RVSM issue in tactical aircraft. Its current plan is to continue mass movement of tactical aircraft by air-capable ship or by making use of altitude reservations. For nontactical aircraft, the decision will be made platform by platform whether to make the investment to gain compliance or pay the penalty for noncompliance.

4.7.2 Required Navigation Performance-10

When RNP-10 is implemented in the Pacific on 23 April 1998, access to the 50-nmi reduced-separation RNP-10 tracks will be denied, or restricted to flight levels below 290. The effects will range from longer flight times and increased fuel consumption to reduced aircraft payloads and schedule disruptions due to an inability to obtain a crossing slot time.

Air Force transports, tankers, and large special-use aircraft (E-3, E-4, E-8, EC-130E/H, HC-130, and R/O/TC-135) are expected to be impacted by RNP-10 implementation and will need to comply to maintain a worldwide deployment capability. No impact on Air Force fighters or bombers is anticipated. Because Navy operations in the Pacific are primarily carrier-based, RNP-10 implementation is expected to have minimal impact on naval operations.

4.7.3 Basic Area Navigation (RNP-5)

Eurocontrol mandated carriage of RNAV equipment approved for RNP-5 operations on the entire ATS route network in the ECAC area beginning 23 April 1998. RNAV on standard arrival and departure routes will be incrementally phased in. The first BRNAV routes (en route) were implemented in July 1998; they will be greatly expanded with the 8 October implementation of version 3 of the route structure. Complete phase-in will probably take up to 2 years. Non-BRNAV military traffic may continue to use the OAT route structure. NATO has requested that special procedures allowing minimum restrictions be provided to military aircraft occasionally operating as GAT, but noncompliant aircraft will probably receive nonoptimal routes and/or altitudes. Air Force tankers, transports, and large special-use aircraft that operate in Europe are expected to be impacted by BRNAV implementation. The Navy anticipates minimal impact because of its infrequent use of European bases and the commitment to implement an integrated GPS/INS solution that meets the intent of RNP-5 in its tactical aircraft.

4.7.4 RNP-4

Pacific airspace planning groups plan to mandate RNP-4 (in conjunction with ADS and oceanic datalink) in 2003–2005 in dense oceanic airspace in the Pacific to support reduction of horizontal separations to 30 nmi. Noncompliant aircraft will receive nonoptimal routes and/or altitudes. Air Force transports, tankers, and large special-use aircraft that operate in the Pacific are expected to be impacted. As with RNP-10, the impact on naval operations is expected to be minimal because of the nature of Navy operations in oceanic airspace. The Navy does, however, have plans to achieve navigation accuracy comparable to that required for RNP-4.

4.7.5 RNP-1

Eurocontrol proposes that a decision on mandatory carriage of RNAV equipment meeting RNP-1 PRNAV requirements be made by the ECAC member states in 1998; they do not foresee implementation of RNP-1 equipment before 2005, and expect to maintain VOR and DME NAVAIDs until at least that date. The United States has also considered plans for migrating to an RNP-1 capability, but no implementation plans have been made. It is possible that RNP-1 might require coupled operations to eliminate the flight technical error associated with allowing a pilot's hands on the controls. It is expected that noncompliant aircraft will receive handling delays or nonoptimal routes and/or altitudes. All Air Force platforms that operate in Europe are expected to be impacted by PRNAV to some degree but the impact cannot be quantified until the CONOPS for RNP-1 is better defined. The Navy has no plans to upgrade its aircraft and navigation capabilities to achieve RNP-1 standards.

The United States plans to migrate to GPS-based navigation (whether defined in terms of RNP-1 or not) will affect a wide range of Air Force aircraft that operate in CONUS as ground-based NAVAIDs are decommissioned.

4.8 SURVEILLANCE

4.8.1 Automatic Dependent Surveillance—Addressed

Pacific regional groups plan to mandate ADS-A (along with RNP-4 and oceanic datalink) in 2003–2005 for all densely used oceanic airspace. North Atlantic groups have similar plans for ADS-A implementation, though no mandatory carriage date has been set. Noncompliance will

result in nonoptimal routes, longer flight times, increased fuel consumption, and reduced payloads. All aircraft that are impacted by the oceanic datalink and RNP-4 requirements (Air Force tankers, transports, and large special-use aircraft) are expected to be affected by ADS-A implementation. Navy aircraft are not expected to be significantly affected by oceanic ADS requirements.

4.8.2 Automatic Dependent Surveillance—Broadcast

Both Europe and the United States are developing plans for line-of-sight ADS-B systems for air-air and air-ground use. The U.S. plans for ADS-B are based on Mode S/GPS squitter, and European plans are leaning toward S-TDMA VHF. Numerous applications for the ADS-B datalink, focusing on continental airspace, are being investigated, including cockpit display of traffic information (CDTI). It is expected that a large number of Air Force platforms will be affected when ADS-B is implemented on a widespread basis and begins to supplant ground-based SSRs, but specific effects cannot be determined until the ADS-B concepts of operation for the United States and Europe are better defined. Noncompliance could result in the inability to operate IFR within the respective national airspace systems.

Naval aircraft assigned missions that routinely operate in areas where an ADS-B capability is required will be equipped to do so. The equipage will be accomplished platform by platform, based on possible military utility and the platform sponsor's success in the budget process. It goes without saying that carriage of some equipment (ADS-B may be an example) might be mandated for flight safety, similar to that experienced with Mode C.

4.8.3 TCAS

The Nav/Safety Board has recommended TCAS equipage for all passenger- and troop-carrying Air Force aircraft. In addition to its use for separation assurance in continental airspace, TCAS is used to support in-trail climb and descent procedures in some oceanic airspace, and this use is likely to expand. TCAS may eventually be a required capability for access to reduced separation tracks in dense oceanic airspace as well. Aircraft that are not equipped with TCAS will not be able to take advantage of procedures based on its use or access tracks where it is mandatory equipage. Effects range from longer flight times and increased fuel consumption to loss of access to certain airfields and an inability to perform certain missions or flight profiles in the affected airspace. Air Force tankers, transports, and large special-use aircraft will be impacted by this requirement.

If the military decides to follow the civil TCAS requirement in continental airspace, the number of aircraft affected would increase. Civil mandates for TCAS equipage are based on passenger capacity in the United States and on aircraft weight and/or passenger capacity in Europe, so it is expected that passenger-carrying and large aircraft would be most impacted by such a decision.

The Navy is providing a limited TCAS capability for its training aircraft. TCAS is being implemented on a platform basis for selected Navy passenger-carrying aircraft.

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Chapter 5—GANS Technology Needs

5.1 INTRODUCTION

Considerable civilian and military technologies have been developed in the GANS technical areas, and more are under development. Successful final development and deployment of all of these emerging systems and technologies are yet to be accomplished. These development and implementation programs are directed to diverse end capabilities and will provide a variety of equipment configuration mixes. To determine the most cost-effective path for the integration and implementation of these technology areas is the major challenge to GANS implementation.

A major component lacking in these technology developments is the focus on an integrated GANS implementation approach to military utility in the face of civilian compatibility. The various development efforts directed at specific goals within the individual supporting programs may not be using the appropriate technology to meet cross-program objectives. The definition of common interfaces among these various programs may lead to implementation problems and become a significant technology area in itself stimulated by GANS.

5.2 GANS TECHNOLOGY

A major challenge is the ability to manage GANS technology across program and system boundaries. Today's systems are more interactive than ever before. No longer can systems or subsystems stand alone; rather, they are interconnected and so intermeshed that it is difficult to determine critical paths and elements for overall aircraft missions. Data and sensor input generated by multiple systems are, in many cases, still processed independently. The interoperability between systems could well become a technology development area in itself.

Within the conventional DoD science and technology (S&T) program, the focus is on devices and systems that perform specific functions. These efforts and those in industry support in turn the rapid evolution of technological advancement driving commercial enterprise and product development. Developments in commercial technology have adapted to technological interaction and concepts in integrated systems. In fact, many advances are driven by development of inter-system technologies or combinations of technologies into new functions or capabilities. The Internet is a prime example of successful cross-system integration using a variety of dissimilar technologies. Within DoD systems development, this adaptation or interactive system development has not yet been successfully accomplished. The structure of the platform-development programs for devices and systems normally focuses on individual mission area or system requirements. Intersystem requirements are difficult to define, and interface efforts, which have been the usual method of addressing intersystem requirements, have little support in the S&T program.

Technology needs that support GANS requirements should include support for developments in the mainstream CNS technology areas. GPS and augmentation systems, such as WAAS, which are the backbone of a GANS architecture, should be a prime focus for technology support. GPS receiving equipment has been applied to increase military utility in a number of areas, and integration with civilian airspace requirements will add yet another dimension.

5.3 GPS TECHNOLOGY

Development of GPS is at a major turning point in its deployment. The redefinition of the system to address new civilian and revised military functional areas is in process. The GANS requirements should be a major consideration in system redefinition. The result of these activities in the near term will most probably be a variety of user equipment options and architectures that may be retrofitted or replaced with new equipment. This retrofit or replacement is a major cost driver.

5.3.1 GPS User Equipment

The GPS user equipment capability to operate in theater military operations and compatibly with civilian airspace will be highly dependent on the functionality of that equipment. Civilian GPS equipment, which is driving the economies in reduced equipment cost and availability of units, is not suitable for military tactical operations. As a consequence, Precise Positioning Service (PPS) user equipment designed for military operation has not benefited fully from this economy of scale. PPS receiving equipment does not have the necessary diversity of quality sources and functionality.

A major advanced technology effort is going on to assure GPS access to the military user. New technologies, equipment, and modes of operation are being examined to provide the necessary equipment for operation in a wartime environment. Difficult problems still must be overcome to operate in P(Y) code only and provide the signal protection margins necessary. Technology efforts to develop multiple correlator subsystems and rapid P(Y) code acquisition techniques are continuing.

The other major component of rapid acquisition is more stable user equipment local oscillators or clocks. More emphasis is needed in local oscillator improvement and interfaces to other systems to enable time synchronization as an aid to initial P(Y) code synchronization. Other technology efforts into ionospheric and tropospheric error contributions are examining the impact of solar maximum and modeling efforts on user equipment. The ionospheric error in the user equipment can take the form of excess ranging error and signal scintillation effects. Improved and alternative error correction and the impact of possible scintillation are being developed for possible use in military systems.

The integration of GPS equipment with other systems has been dealt with mostly by platform programs having components developed within the GPS program. Subsequent integration of developed GPS user systems, many with different functionality and performance, with other onboard systems and sensors has required tailored implementation in the various aircraft platforms. The GPS equipment retrofit program should be designed to combine equipment modifications to reduce the integration necessary. The extent of the modifications required may not be within the capability of the PPS equipment currently deployed. These modifications include the addition of integrity functionality, capability to meet landing position and velocity requirements, and interfacing with the datalink systems in the en route and ATC systems. These modifications, in concert with the military requirements for secure communications, resistance to jamming environments, and incorporation into military SA systems, will require considerably different equipment than that currently deployed.

5.3.2 GPS Space and Control Segment

The GPS Space and Control Segment maintains GPS operation for both civilian and military use, based on the principle that technology efforts should augment, not jeopardize, user equipment deployment. Air Force leadership in the stewardship of the GPS program will depend heavily on successful maintenance of the basic GPS Space Segment capability.

Technology efforts for the system are focused on basic system accuracy improvement and improved visibility for monitoring the satellite constellation. Technology efforts are adjunct to upgrades by the operational command in the ground electronics systems and re-architecture of tracking and computer systems. A change that has been incorporated into the space segment is directed at improving the satellite-predicted clock error, which is one of the largest error sources in GPS navigation. An augmented data field has been incorporated in the GPS satellite navigation message to provide an update of all satellite clock predictions in each message. This technique, known as Wide Area GPS Enhancement (WAGE), has been demonstrated to provide increased accuracy to the suitably modified user. This augmented data field is planned to be continued until the satellites with ranging and data cross-linking can be established and the AUTONAV concept initialized.

Another near-term technology effort, known as the Accuracy Improvement Initiative (AII), is to incorporate techniques for improving GPS accuracy. The five elements of AII are:

- Increasing the frequency of uploading the satellite data by the Operational Control Segment (OCS)
- Incorporating six National Imaging and Mapping Agency (NIMA) monitor stations into the OCS network to increase visibility of the satellite constellation
- Implementing the Air Force Satellite Control Network automated remote tracking station (ARTS) interface so that upload may be performed through any ARTS-compatible station
- Implementing a single partition capability in the legacy OCS Kalman filter, which generates the navigation data for the satellites and user navigation messages
- Implementing the capability of using up to 14 NIMA monitor stations in the system Kalman filter with the new OCS architecture. This initiative will not require any modification to the user equipment to benefit from increased accuracy.

The expansion of the ground infrastructure is coupled with the introduction of AUTONAV into the next block of satellites. AUTONAV in fully autonomous mode would enable the satellites to communicate data and determine range between satellites, synchronize the onboard clocks in orbit, and compute, for transmission in the satellite navigation message, all the data necessary for the user to accurately navigate. The ability to operate the constellation in fully autonomous mode is designed to reduce or eliminate the requirements for a large ground infrastructure. The tradeoffs in AUTONAV operation and ground infrastructure will be balanced with satellite constellation visibility, system accuracy, and cost. Cross-linking significantly increases satellite constellation visibility, since a single station could, in principle, communicate with all the satellites through the crosslink. This capability for full communication will not be possible until after 2015, when the majority of the satellites will be from Block IIF. Synchronization of the on-orbit clocks and UTC offset data should be closely examined in order to maintain system and absolute timing accuracy.

Augmentation of the ground tracking network to increase the visibility of the satellites for anomaly detection and correction is necessary to support the stewardship and basic operation of the system. The portion of the system that supports the infrastructure needed for time synchronization and

dissemination needs redefinition as well. The link to international Universal Time Coordinated (UTC) maintained for U.S. systems is currently a monitoring function by the Naval Observatory (USNO) and the Alternate Master Clock (AMC) at Falcon AFB between GPS Time (for navigation) and UTC maintained by USNO, UTC (USNO). To achieve the system increased accuracy goals, closer coordination between GPS Time and global timing centers will be required. An alternative to increasing linkages between these various system elements and centers is to incorporate these U.S. elements into a single U.S. timescale system. Incorporation of the atomic clocks used in the GPS and augmentation systems and the timescales at the USNO and the National Institute of Standards and Technology could provide a single coordinated timescale for all U.S. military and civilian systems. International coordination of this single timescale for civilian, allied and NATO use would provide better accuracy and synchronization of all GATM/GANS and associated systems.

Technology needs for the GPS space and ground segments are for spacecraft sensors and systems with longer life, and for associated improved ground tracking and data communication systems. Improved spacecraft subsystems to support the increasingly longer, more reliable operating lifetimes are needed, particularly in stabilization and power-generation subsystems. The primary spaceborne navigation subsystem technology need is in reliable long-life atomic clocks and timing subsystems to provide stable and precise synchronization with an uninterrupted continuous signal. Tracking and data communications systems deployed to provide sufficient visibility of the satellite constellation need enhanced monitoring, telecommand subsystems and uninterruptable timing subsystems. Techniques for integration of diverse satellite tracking data types from civilian sites could complement the ability to compute and provide data for position and synchronization updates in near-real time.

Chapter 6—Acquisition Strategy

6.1 INTRODUCTION

The Global Access, Navigation, and Safety acquisition strategy encompasses several related but diverse programs, a system of systems. The GPS and ground infrastructure acquisition strategies are well established. The aviation platform-related programs of the Global Access, Navigation, and Safety initiatives acquisition strategy are less clear; they are highly complex, covering a wide range of applications and long-term requirements over a large number of aircraft. Moreover, CNS/ATM needs must be viewed in a broader context, which includes related functions, systems, and equipment on Air Force platforms. Because of their application to all aircraft operating in a global environment, the acquisition strategy for this complex program may require an innovative and streamlined strategy to satisfy requirements that are being developed by outside entities.

6.2 PROPOSED STRATEGY

Three overriding conditions determine the direction of the strategy.

- First, CNS/ATM is not optional. Enhanced military utility and operational effectiveness gained by the incorporation of the CNS/ATM systems will be significant. CNS/ATM will allow the U.S. military to operate unrestricted in the global environment and be interoperable with the commercial air fleets. It is assumed all operational workarounds have already been taken advantage of and that the remaining requirements have a hardware and software solution.
- Second, the Air Force's aircraft fleet must be evaluated for compliance and upgraded accordingly to meet the timelines required for their prioritized mission requirements. DoD is investigating the use of specific military capabilities in addition to new equipment to achieve compliance. The planned modification program for each model, design, or series should be examined to determine additional changes (CNS/ATM-related) required to become CNS/ATM-compliant. The advantages of modifying other related avionics to improve reliability, decrease maintainability costs, and increase availability should be considered as possible payback sources for the CNS/ATM modification. This payback should include appropriate incentives to share in the ideas brought forward for incorporation.
- Last, an integrated solution is the preferred methodology to become CNS/ATM-compliant. Most improvements and enhancements for military utility are gained by integrated solutions. An integrated approach can also realize future growth potential. The integrated solution should be implemented in blocks or phases to match the time-sequenced requirements, standards, and associated processes as they are brought to maturity by the international aviation community and ATC entities.

DoD must solve a number of challenges to provide global access to its airspace users. The problems can be solved by a combination of existing military capabilities, operational workarounds, and an imaginative and innovative acquisition strategy. In compliance with the DoD budget process, we must plan, fund, implement, and modify a wide variety of aircraft fleets in an environment of near-term firm requirements out to more indefinite requirements for the longer term. The Air Force should be able to adapt to a fluid multiple-architecture environment, in which each aircraft single manager has a planned acquisition for that aircraft fleet. Domestic and international agencies and air carriers are required to participate in the solution, often driven by compressed timelines.

DoD, desiring to retain global access, finds itself inside lead-time requirements and without planned funds to cover this significant program. The operational impact for noncompliance is airplane exclusion from a given airspace, or unavailability of certain ATC services (see Chapter 7 for more detailed discussion of this topic). This penalty has significant impacts on cost, manpower, closure, and operational effectiveness. Therefore, a strategy that takes advantage of ongoing commercial and military innovative practices is necessary to offset the up-front cost challenge and decrease the time for compliance. Furthermore, the maximum use of high-level performance specifications should be encouraged to allow the greatest flexibility in program management.

Since the CNS/ATM program is so closely related to the civilian air carriers' efforts and compliance with FAA directives, DoD should receive the legislative relief that the FAA enjoys with regard to adherence to the FARs and acquisition streamlining. This legislation promotes and allows much closer cooperation between the government and contractors—and cooperation will be required for timely execution of this program.

6.2.1 Funding Paradigm Shift

The acquisition strategy should be based on intelligent partnering or teaming between two partners: the Air Force and the defense industry. The Air Force should determine overall system requirements and provide overall program management responsibility. The industry partner should provide the overall CNS/ATM solution to be upgradable, meet the required timelines, and reduce government risk. Initial industry response to performing this effort has shown that financial alternatives are available to reduce the up-front costs and smooth the funding stream to a minimum level for a definite period of time to enhance our planning ability. This could be done via a financial broker using commercial techniques to provide installment sale capital while holding a security interest. This alternative would require further investigation, but it is a readily used technique in the commercial world.

The industry partner could also include avionics supplier team members, which could bring commercial technology to the CNS/ATM solution. There are adequate suppliers that could provide the CNS/ATM-compliant line-replaceable units and warranty repair if desired. Instead of a traditional acquisition program, a contract for service could be executed that would pay a contractor a fee for technology insertion and integration, or a more general fee for "global access." In such a fee-for-service arrangement, the CNS/ATM equipment could be provided free of charge, with all the appropriate clauses included to protect the government's rights and liability. In particular, the liability question could be based on a depreciation schedule agreed to in advance, determined by the mean time between failures (MTBF) or shelf life of the technology; this would decrease the cost of the liability to the government.

6.3 PROPOSED PROGRAM MANAGEMENT

The study group considers the Global Access, Navigation, and Safety requirements to include three main areas (see Chapter 5 for more discussion on this topic):

- Achieve global access through the tenets of communication, required navigation performance, SA, and ATM
- Leverage existing C² capabilities
- Integrate the network ATC vision with DoD Global Grid, data fusion, and decision tools

The study panel has concluded that Global Access, Navigation, and Safety products will improve military capabilities such as C².

The CNS/ATM program should be managed as a “system of systems” program that integrates GPS, ground environment, and aircraft systems to allow global access. Integration is required to meld the interests of the Major Commands (MAJCOMS), civil aviation authorities, and single managers. This will require planning, programming, and budgeting efforts over a long time to provide the necessary resources. The program should follow the principle of fusing the requirements and acquisition teams to buy once and field faster. The spiral development process should be used to buy smart and field better systems. Minimum integration and minimum costs should be achieved by opening the aircraft for modification once to lessen the costs.

Some of the Air Force’s platforms can benefit from installing an open integrated modular architecture that integrates functions onto a redundant, distributed multiprocessor system. Integration offers many benefits, including lower weight, lower power consumption, increased reliability, less frequent maintenance, and greater flexibility. But, because these functions share hardware resources, greater care must be taken to ensure that they can meet their varying real-time requirements, even if coresident functions fail. One integration challenge is that the functions are a mix of hard real-time functions (engine-data interface, data conversion gateway, display system, flight management acquisition, flight management, and thrust management) and non-real time (central maintenance and data communications management).

The acquisition advantages of an open integrated modular architecture are:

- Civilian design and implementation for nonmilitary-unique requirements; share initial and change development costs with civilian air fleets
- Modular and open architecture for new systems when supported by life-cycle cost estimates; lower regression cost for certification or flight qualification releases
- Planned software upgrades
- Hardware (card) updates or replacements to upgrade technology (for modular systems)
 - Replace low-MTBF parts or obsolescent components with new technology
 - Reduce depot infrastructure but increase initial integration and installation costs
 - Decrease overall integration and installation costs for modifications
- Payback from one Global Access, Navigation, and Safety area to fund another within the same weapon system
- Reliability, maintainability, and availability savings from avionics modernization to fund other parts of Global Access, Navigation, and Safety
 - Some weapon systems are replacing low-MTBF parts with high-MTBF parts
 - Squadron O&M potentially reduced by 25 percent or more

This type of architecture not only offers faster development and integration time, but provides advantages over the life cycle of the system. Integration plays a significant role in reducing production cost, since resources can be shared across multiple functions. That means that less hardware is needed to implement the functions. Since there is less hardware, the reliability automatically improves. Reliability is the major factor in maintenance and sparing costs. Common units reduce development costs by requiring fewer designs. They also reduce the number of types of spares required. Since the architecture is implemented with a few designs

used many times, only a few components have to be developed. Cost of ownership decreases. Boeing's 777 avionics program has demonstrated a 50 percent reduction in size, weight, and power; increased system reliability by a factor of 2; and development cycle reduced by 20 percent. These things resulted in a 40 percent lower acquisition cost. This approach may be less cost-effective in retrofitting the current fleet than in developing a new platform. The platform life-cycle cost with several technology insertions and software modifications must be considered.

Finally, against the need for increased functional capability and growth, the open integrated modular architecture is ideally suited to fit that requirement. As long as the platform requirements are being further defined in the future and tasked to perform more functions than originally designed for, a capability for future cheap modifications is the most significant life-cycle cost driver. The architecture has the ability to effectively absorb additional computer modules or input/output modules without significant redesign.

The acquisition plan should contain the methodology to manage the program information. This methodology should build and track to a strategic plan that includes justification and rationale for the resources required in the Program Objective Memorandum (POM) period. The program direction should ensure that the CNS/ATM system is built to a common operating environment (COE). The COE will assist in developing a common understanding of the requirement, allow system trades to be made across multiple programs, and provide a baseline technical architecture and certification.

6.3.1 Funding Process

The second key ingredient of the acquisition plan is the direction for the management of the program funds. The plan should build a funding strategy to execute the plan. This strategy will facilitate trades to be made and assure that commonality is used when it makes sense. An obvious choice needs to be made with regard to the centralized versus decentralized control of all program funds.

The funding strategy should balance the necessary program flexibility with the desired control. A number of funding options are available for program execution. At one end of the spectrum, the platform single managers would be in control. At the other end, the CNS/ATM would centrally control all development, procurement, and integration funds.

Advantages of this funding strategy are:

- Ease of preparing consolidated POM rationale
- Ease of tracking funding and execution
- Increased visibility of program
- Broad common architecture developed
- Ease of coordination
- Parallel effort maximized
- Champion for best Air Force solution
- Maximum funding flexibility
- Central control for architecture and solution

Disadvantages of this funding strategy are:

- Funding pool will be about \$1.7 billion per year
- Ease of using this common pool of funds to pay for unexpected Air Force bills
- Platform Program Element Monitors (PEMs) and System Program Directors (SPDs) are not fighting for Global Access, Navigation, and Safety dollars in the Air Force corporate structure
- Large portions of Group B equipment in this estimate are highly integrated into single platform SPD implementation schedules
- Could disrupt SPD installation plans to minimize platform downtime when combining programs. The GATO/MC2 SPO could decide to slip 10% of its funds to another year and destroy the platform SPD's schedule
- Navigation safety is currently tracked by one PEM (XORFM) across all platforms with all the funding in each individual platform PEs

Minimizing the disadvantages and maximizing the advantages would give all the development and the NRE funding for each platform to the GATO/MC2 SPO, which would then release funds to the platform SPO to integrate the CNS/ATM solution equipment set and test procedures to implement the MAJCOMS' operational CNS/ATM requirements. This would reduce the PE target to several hundred million dollars per year and is defensible by which platform they are planning to support.

6.3.2 Cost Avoidance

The single largest contributor to the high cost estimate is the estimated separate federated installation. Because the ICAO environment is evolving over time, a single solution set cannot be selected until well after most aircraft operations will be severely hindered, approximately after 2008 or later. Even then, the Air Force can expect the ICAO ATM environment to be modified and adjusted to increase safety margins and to increase efficiently. After ground bottlenecks are solved, the air bottleneck will again be the limiting factor. Therefore, the single most effective cost reduction area will be integration. Architecture selection based on reducing the costs of designing and installing modifications instead of minimizing initial installation costs can significantly reduce life-cycle costs. In the near term, the CNS/ATM solution can be guessed today, but the SPD would later need to install JPALS and NAVWAR solutions anyway along with changes to the guessed CNS/ATM solution.

If the Air Force reduces the cost of hardware 10 percent it will gain only 10 percent in savings. If the Air Force invests in installing an open architecture, it will save on modification installation and integration costs. Current industry results show a 30 percent to 40 percent reduction of installation and integration costs for open modular systems. Current estimates have the integration costs at 10 to 20 times the hardware costs for federated systems. Therefore, a 10 percent reduction in integration costs can increase cost savings by a factor of 10 to 20.

SPDs need to investigate restructuring their platform's architecture to an open modular design. This would allow lower modification integration costs in the future, which would pay for the higher installation costs. This lower cost would allow for deploying future changes to the global airspace environment.

Approximately 50 percent of the FY98 PB aircraft modification funding is for programs that upgrade or install avionics, datalinks, communications, databuses, and displays. Many of these

programs are based on the conclusions of prior-year programs and are prohibitively costly to change. SPDs must reexamine their modification programs to leverage the synergism of combining requirements to implement the individual Global Access, Navigation, and Safety program to minimize platform downtime and cost. The \$7 billion to \$10 billion anticipated bill will partly be paid for from some of these existing funded mod programs. The FY98 PB P3X report (FY97-FY04) on the aircraft mod program is \$12.7 billion. Even if only 25 percent of the current PB can be altered to meet GANS requirements, that would reduce the anticipated bill by \$3.2 billion. Installing combined systems and an open modular architecture can decrease future modifications costs by 30 percent or more and pay back the investment in 4 years.

Finally, system engineering and program management costs (now 10 percent to 20 percent of totals) can and must be reduced by innovative simplification of the management process similar to the method adopted by the R&D community in system development (Section 845—Other Agreements). Legislative relief could be required to accelerate the acquisition process similar to the FAA relief.

Chapter 7—The Air Force in a Leadership Role

7.1 MEETING MILITARY AVIATION NEEDS IN TIMES OF AVIATION CHANGE

The Air Force must lead DoD in assuring that military capability is sustained during the evolving transition to new global aviation architectures. So far, at the policy level, the military has been an inactive observer while the civil aviation community has charted a path to “free flight” technology that requires significant technological change over the next 15 years. There is an opportunity to significantly influence this transition to meet military needs. This, however, speaks for active engagement by military leadership at the highest levels. Currently no one senior-level officer has been charged with the overall task of assuring unrestricted global access for military aviation operations or assuring that DoD interests are effectively protected in the transition.

7.1.1 The Historical Air Force Role

The Air Force historically has had a role in developing and refining navigation around the world. From the earliest days through the creative days of the 1930s and 40s, the Army Air Force and the Navy established the infrastructure and operational procedures that led to the phenomenal global navigation system of today. Blind flight, over-water legs, and refueling were established in the best traditions of the fledgling air forces in the Army and Navy. This leadership continued after WWII when the commercial industry responded to the technological successes of military airplane builders. This growth in technological capability led to great commercial aviation success and American leadership in aviation. This transition has come full circle and, paradoxically, commercial aviation is leading the military aviation industry today. The role of DoD leadership requires reevaluation to assure that national security interests are incorporated appropriately in evolving civil aviation architectures.

7.1.2 Assignment of Accountability

The logical choice for leadership in achieving this role for DoD worldwide is CINC TRANSCOM, who is responsible for movement of people, supplies, and warfighters, and has the potential to provide a high-level platform that can be leveraged into an international CNS/ATM leadership role. There are mechanisms to formally transmit and negotiate these needs through the DoD–Department of Transportation (DOT) Pos/Nav Executive Committee and the newly formed Intergovernmental Executive Board for the joint management of GPS as specified in the Presidential Decision Directive. The DoD Under Secretary for Acquisition is the designated chairman of both committees, which present the logical path to presenting military needs in civil aviation. The operational leader for these efforts should be the CINC TRANSCOM working with the chairman. One tasking that should emerge from this leadership role should be the endorsement of GPS coupled with a global communications grid that assures timely decision-making as the backbone of DoD navigation, landing, and surveillance systems.

7.1.3 Strategy

The upcoming revolution in worldwide aviation activities will require a significant allocation of resources to assure global military aviation flexibility. Just the cost to modify aircraft could reach \$6 billion or more.

This potential outyear liability argues for central management of requirements, resources, and current diffuse and fragmented but well-intentioned efforts.

High-level leadership is required to structure a coherent technical, political, and budget strategy to assure that military needs are adequately addressed in the civil/military conversion. The current GATM is a conglomeration of a large number of technologies. These must be integrated into systems in new ways and require new CONOPS. Given the large range of proposed implementation dates and the cost of adopting these technologies and concepts, the commercial sector has expressed great uncertainty as to what to adopt and when to adopt it.

The commercial sector does not want to adopt costly technologies too soon, when there is some chance that technologies may shift and require new spending. Leadership should be applied in DoD to assure that this same quandary does not extend to the budget-constrained military. Given this commercial uncertainty, there is room for leadership from DoD.

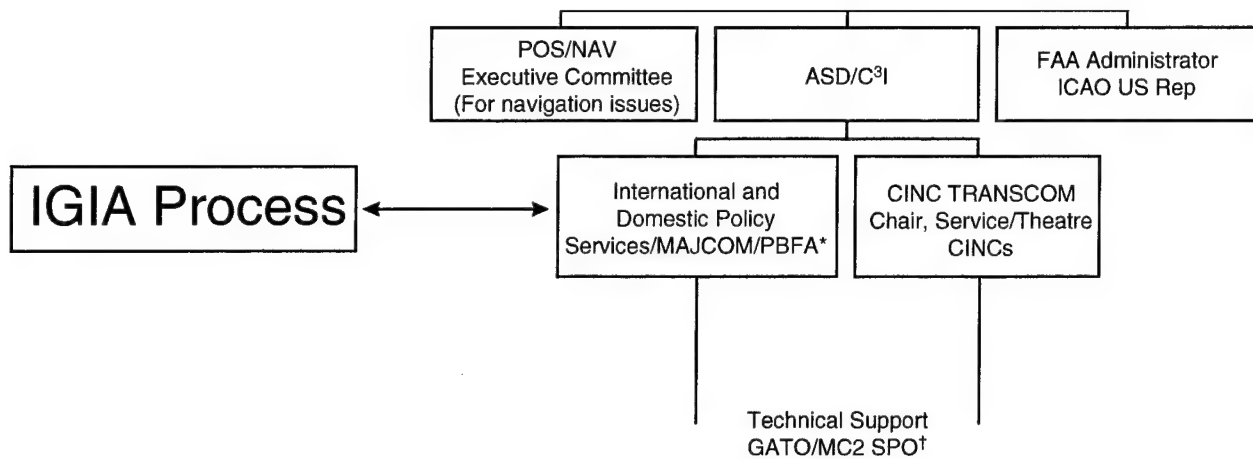
7.1.4 Options

The options for DoD are to do nothing, to react to civil requirements, or to help shape the conversion:

- **Do nothing.** The option of doing nothing is based on the view that GATM is a commercially driven burden on the Air Force that does not enhance capabilities and is irrelevant in a warfighting situation (that is, it is a peacetime set of concepts). This option is not really a choice because of its impact on combat deployments. Nonadoption of GATM will lead to exclusion from commercial routes over the Pacific and Atlantic and to substantially increased time to deploy forces to overseas locations.
- **React to civil requirements.** The option of only reacting to the commercial world will lead to unacceptable costs and place the DoD budget at the mercy of civil decisions without appropriate DoD input.
- **Help shape the conversion.** DoD is a large user and provider of aircraft services; it should step up and lead to a set of choices that maximize military capability while minimizing costs. DoD has the assets and vision to promote in the commercial world new concepts that are essential to preserving military capability.

7.1.5 Recommendation

Faced with these challenges, military accountability for this conversion must be placed at the highest levels in the U.S. Air Force and DoD. The logical position for GANS leadership is at a CINC with responsibility for movement of forces.



* Participates in regional planning groups to influence requirement development

† Participates in RTCA/AEEC technical architecture meetings

Figure 3. DoD Influence on CNS/ATM System Requirements

The key question that must be answered is not just how DoD influences policy, or how it influences technology; the question is how DoD influences the process (see Figure 3). By the time an issue reaches the policy level, it may be too late to do anything but say yes or no. DoD must be involved at the working-group level with the organizations implementing these changes in order to know well ahead of time what is coming, enabling us to assess the impact in time to influence the process. The key players in development and implementation of new policies affecting the global airspace architecture, such as development of CNS/ATM systems, are ICAO, regional air navigation planning groups, NATO, and the FAA. Real-world implementation is most often carried out by the regional planning groups, both formal and informal.

7.2 INTERNATIONAL PROCESS

ICAO is an independent body of the United Nations. The ICAO Assembly is the sovereign body, dealing with broad policy issues; each member state has one vote in the Assembly. The ICAO Council is the governing body, with 33 representatives from member states.

One of the Council's principal duties is the adoption of SARPs. ICAO has no regulatory authority. It is the responsibility of the member states' CAAs to convert the SARPs into regulations and to notify ICAO of any differences between their national regulations and the SARPs; if a member state implements a system for which SARPs have been established, that system must comply with the applicable SARPs. The Air Navigation Commission (ANC), appointed by the ICAO Council, is responsible for coordinating and planning all of ICAO's air navigation work and has primary responsibility for SARPs development through numerous technical panels and study groups. Policy recommendations on SARPs development and adoption are made at ICAO Communications/Operations Divisional (COM/DIV) meetings every 3 to 5 years and at ICAO panel meetings.

The U.S. mission at ICAO headquarters in Montreal represents U.S. interests in all technical, budgetary, political, and administrative issues. It is an office of the Department of State (DoS), and includes the U.S. Representative to ICAO (Council Member), Ms. Carol J. Carmody; the

ANC Member and Deputy U.S. Representative, Mr. Frank Price; and the Political/Economics Officer, Mr. Jack Orlando.

7.2.1 Regional Airspace/Navigation Planning

An important forum for DoD involvement in CNS/ATM system development is regional airspace/navigation planning groups. There are five official regional air navigation planning groups established by the ICAO Council: NATSPG, EANPG, the Africa–Indian Ocean Region Planning and Implementation Regional Group (APIRG), the Caribbean/South American Regional Planning and Implementation Group (GREPECAS), and the Asia/Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG). Of these, NATSPG and EANPG are the most active, though APANPIRG is heard from occasionally. NATSPG was responsible for the recent implementation of RVSM in the North Atlantic. The EANPG, working with Eurocontrol, is responsible for planning and implementation of new European ATM systems, including 8.33-kHz VHF voice, BRNAV, protected ILS, ACAS, and Mode S.

In the Pacific, much of the regional planning is actually carried out by unofficial groups, particularly ISPACG and IPACG. ISPACG was responsible for implementation of FANS-1 in the South Pacific and for developing and adopting reduced lateral-separation standards in that region. IPACG was responsible for RNP-10 implementation and is planning for RVSM, and—eventually—“CNS” (RNP-4, CPDLC, and ADS) implementation in the North and Central Pacific. Although IPACG and ISPACG are not official ICAO regional planning groups, their members include the FAA and other CAAs. The member state CAAs then bring these regional plans into the official ICAO process through the formal regional planning group (APANPIRG) or the ICAO regional office in Bangkok for incorporation into official ICAO documents such as the Regional Supplementary Procedures (ICAO Doc. 7030). Plans formulated at the ninth meeting of the IPACG (November 1995) have been endorsed by both the FAA and JCAB, paving the way for CNS/ATM implementation in North and Central Pacific airspace.

DoD participation in the informal groups appears to be welcome; the Air Force has participated—on a somewhat sporadic basis—in some of these regional planning groups for some time. Participation in formal ICAO regional groups (NATSPG and EANPG) requires coordination through PBFA with the FAA to obtain an official invitation. However, it can be done and can have an impact. This was illustrated in the implementation of RVSM in the North Atlantic.

The original plans for reducing vertical separation in the North Atlantic called for a “big bang” approach: RVSM implementation at all flight levels from 290 to 410 in all MNPS airspace. Through the PBFA and the U.S. representative to the NATSPG (FAA/AAT-30), AFFSA/XN obtained an invitation to attend NATSPG meetings and present DoD’s concerns about this approach.

To prepare this input, the Air Force participated in several international meetings dealing with RVSM implementation issues, including an ICAO/FAA/CAA RVSM seminar and a follow-on meeting with several concerned aviation industry groups, such as the National Business Aircraft Association (NBAA). Eventually it was decided that RVSM would be implemented in phases. The initial phase, which began on 27 March 1997, was implemented only between FLs 330 and 370; workaround altitudes were reserved for noncompliant aircraft, and there is a climb-through procedure for traversing the RVSM altitudes. It is difficult to sort out how much of this change of heart was due to DoD influence and how much to other influences (such as pressure from the NBAA), but it is clear that the new rules’ impact on DoD was a strong factor.

7.2.2 Interagency Coordination Process

Coordinated civil/military U.S. positions on policy/technical issues related to international aviation are developed through the Interagency Group on International Aviation (IGIA) and transmitted to the U.S. Mission. About 95 percent of IGIA cases involve development or coordination of U.S. positions for ICAO meetings (panels, COM/DIV, etc.). The IGIA is chaired by DOT and administered by the FAA through the IGIA Secretariat, located at FAA Headquarters in Washington, DC. IGIA includes the Departments of Defense, State, Commerce, and Transportation; the National Transportation Safety Board; the Federal Communications Commission; and ad hoc members.

When an international aviation issue affecting more than one government agency is identified, the IGIA Chairman identifies a lead government agency to draft the U.S. position and gather inputs from interested sources (including non-IGIA members, industry, etc.). Typically several "IGIA prep" meetings are held to develop strategy, write and review technical supporting documentation, resolve comments, etc. These meetings are at the working/program-management level, and most participants are from the FAA and its contractors, but DoD representatives have also attended. The final coordinated position, which may include information papers from DoD, is presented by the official U.S. delegation (consisting of about five people) at ICAO panel meetings and COM/DIV meetings. In late 1994, for example, the Air Force Electronic Systems Center (ESC) prepared an information paper on "Military Implications of VHF Channel Spacing Changes in the European Region" that was coordinated through IGIA and presented for information by the U.S. delegation at the spring 1995 ICAO COM/DIV meeting.

The Executive Director of the PBFA is the DoD representative to IGIA, and his office (HQ USAF/XOO-CA) is the focal point for DoD distribution of IGIA documents, through HQ USAF/XONP. Service-specific issues are worked by the Service directly with the FAA unless PBFA involvement is specifically requested, but any issue that crosses Service lines becomes a PBFA issue. In principle, the Service Secretary designates the OPR for each issue, but in practice it is usually worked by whoever notices the issue first or is most affected by it.

The PBFA Policy Board (at the three-star level) deals with issues having national implications (for example, the 1980 PATCO strike, Desert Shield/Desert Storm). The Board is chaired by the ASD/C³I. There are also PBFA alternates at the one-star level; the Air Force representative is from HQ USAF/XOO. Some 90 percent of the issues reaching the PBFA are dealt with by the PBFA Working Group, at the O-6 level. This group, which meets about once every 6 weeks, works with the FAA daily, interfacing across many FAA offices. There are approximately 12 primary members, at least one from each Service, as well as representatives from OSD and the General Counsel's Office. The Air Force representative to this group is the Air Force Flight Standards Agency (AFFSA/XA).

The formal process for information distribution to the DoD community ends at the PBFA. In practice, HQ AFFSA/XA often assists the PBFA office in an informal process as the interface to Air Force MAJCOMS and other interested agencies. However, AFFSA has stated that it is not the officially designated DoD or Air Force office responsible for carrying out this process. No one is.

7.2.3 NATO Coordination

The IGIA coordination process is also used to develop and coordinate U.S. positions to NATO, including the NATO ATM Committee (NATMC). The NATMC reports to and develops positions for the MNCers (MNCs) on airspace issues. The two-person U.S. delegation to the NATMC includes one FAA representative and one from AFFSA. The NATMC interfaces with Eurocontrol for civil/military coordination on European airspace issues. In 1996 the two MNCs issued the “Bi-MNCS Statement on the Implications of Civil Aviation Developments on Military Operations”—their policy positions on new CNS systems planned for implementation in European airspace.

NATO is not recognized by ICAO. The 1996 MNC position paper recommends that NATO seek formal recognition by ICAO or, if that is not possible, at least seek to obtain auditor status at ICAO conferences, similar to that of the airline lobbying group, the International Air Transport Association (IATA), “in order to be in the loop of information and, hopefully, on time to influence decision making.”

7.2.4 Domestic Coordination

The DoD PBFA is also the focal point for interaction between DoD and the FAA. There are five military representatives, including one liaison officer (at the O-5/O-6 level) representing each Service, at FAA headquarters. The NAS Plan Requirements Office is also located at HQ FAA, along with some 15 military-reimbursable positions—that is, military officers working directly for the FAA, at HQ FAA, at Oklahoma City, and at the FAA Tech Center in Atlantic City. The Air Force liaison to HQ FAA is organizationally part of XOO-CA. The Air Force has representatives (AFREPs) at five of the six regional FAA headquarters who report to him. These AFREPS deal primarily with day-to-day issues such as coordination of special-use airspace (SUA).

Most military/FAA liaison activity appears to be focused on ground system implementation and airspace coordination issues. Given the major airspace changes being planned under the CNS/ATM concept, this focus needs to be widened to include all GATM issues. It is important that DoD interact with FAA flight standards, air traffic procedures, international procedures, spectrum management, aircraft certification, and other offices to get the complete CNS/ATM picture, whether through assignment of additional liaison officers or some other mechanism. The civil aviation community often complains that there are too many FAAs; a DoD network of FAA interfaces could help identify disconnects. This would require that the DoD liaisons have a forum for discussion among themselves and a mechanism for elevating any disconnects they identify to the appropriate level in the FAA.

Annual DoD/FAA planning meetings are held to facilitate coordination between the two organizations; the lead for arranging these meetings alternates yearly between DoD and the FAA. These meetings appear to concentrate on the ground side, the provision of ATC services. DoD is the single largest user and the second largest provider of ATC services in the NAS, and this role has perhaps forced a certain degree of coordination between DoD and the FAA regarding ground system implementation and operation. No such forcing function has been in place regarding avionics equipage, since the FAA does not have to equip aircraft. At the most recent DoD/FAA planning meeting (11–12 June 1997), the group appeared to be trying to broaden its scope to include avionics issues, but this culture change has not yet been fully assimilated. Many briefers stressed the need for better DoD/FAA coordination, but few had done any more about it than

come to the meeting. Unfortunately it appears that few plans and little action result from these meetings. If these meetings are to be anything more than a forum for status briefings and airing of complaints, stronger leadership and direction will be needed.

Another (informal) avenue for DoD/FAA interaction is the FAA communications/surveillance operational implementation team (C/SOIT). This group was chartered by the FAA Administrator in July 1993. Its main purpose is to promote coordination among the many different FAA organizations involved in implementing new ATC systems and procedures. However, the C/SOIT meetings are also a forum for informal discussion among the FAA, other CAAs, airlines, communications service providers, avionics and airframe manufacturers, aviation industry organizations, and DoD. C/SOIT topics span both technical and regulatory/policy aspects of new CNS/ATM systems.

DoD representatives (from HQ AMC, ESC, AFFSA, the Air Staff, and other organizations) have been participating in C/SOIT meetings irregularly for some time now. The meetings provide an opportunity for DoD representatives to hear updates on standards development, system implementation, and plans; to observe trends in civil aviation; and to meet informally with FAA representatives from many different program offices, including those dealing with air traffic procedures, international procedures, spectrum management, and aircraft certification. Although the C/SOIT has no authority, its FAA members represent most of the critical areas related to CNS/ATM system implementation and can identify issues or disconnects and elevate them through their own management chains.

7.2.5 Technical Standards Development

The two most important technical standards development groups are RTCA and the Airlines Electronic Engineering Committee (AEEC). Both develop technical standards for airborne electronics equipment. Neither has regulatory authority, but RTCA minimum operational performance standards (MOPS) often form the basis for the FAA technical standard order (TSO) that states the requirements for avionics certification, and AEEC standards are widely followed in civil aviation because they promote interoperability and market competition.

RTCA is a U.S. association of government and industry aeronautical organizations, with headquarters in Washington, DC, that develops recommendations for aeronautical electronic and telecommunication systems. Committee members come from airlines, avionics manufacturers, civil aviation authorities, aircraft manufacturers, service providers, Federally Funded Research and Development Centers, trade associations, and other organizations.

Special Committees (SCs) established by RTCA develop and publish MASPS, MOPS, and other documents. The topics to be addressed by special committees are determined by the RTCA Technical Management Committee, a U.S. Federal Advisory Committee. MASPS, which are concerned primarily with the overall system characteristics, define the signal-in-space and the essential features of the transmitting and receiving subsystems. MOPS, which are concerned primarily with the avionics receivers, define performance requirements and verification procedures, equipment performance and environmental conditions, equipment test procedures, installation procedures, and installed equipment performance requirements and test procedures.

The current RTCA special committees that are most relevant to GATM are:

- SC-147: Traffic Alert and Collision Avoidance
- SC-159: Global Positioning System
- SC-165: Aeronautical Mobile Satellite Service
- SC-169: Datalink Communications
- SC-172: VHF Air-Ground Communications
- SC-181: Navigation Standards
- SC-186: Automatic Dependent Surveillance—Broadcast
- SC-187: Mode S Airborne Beacon and Datalink System
- SC-188: High Frequency Datalink
- SC-189: ATS Safety and Interoperability Requirements

The AEEC is a nonprofit organization, sponsored by ARINC and funded by the airlines, that develops standards and characteristics for airborne electronics equipment. The working groups that develop these standards and characteristics are chaired by AEEC staff; members of the working groups come from the airlines, airframe manufacturers, avionics manufacturers, civil aviation authorities, and other organizations. ARINC characteristics specify “form, fit, and function”; that is, form factor, power and cooling requirements, physical and electrical interfaces (to the pin level), and functional system design. ARINC specifications define protocols, waveforms, message sets, and other interoperability characteristics not covered by form, fit, and function.

DoD currently has two representatives on the AEEC. New ARINC characteristics and standards must be approved by the committee before they go final, so DoD has two votes in this process. However, this is an approve/disapprove vote only, and thus of limited utility. In this case the most important involvement is participation at the grassroots level as the standards are developed.

The AEEC groups of greatest relevance to GATM are:

- Data Link Users Forum
- CNS/ATM Users Forum
- Aircraft Separation Assurance System Subcommittee
- HFDL Subcommittee
- Flight Management System (FMS) Subcommittee
- Systems Architecture and Interfaces (SAI) Subcommittee
- Technology Application Group
- Satellite Subcommittee
- Communications Management Subcommittee
- CMU/VHF Digital Radio (VDR) Subcommittee
- Multi-Mode Landing System Subcommittee
- GPS Subcommittee

The SAF/AQ charter to the new GATO/MC2 SPO includes direction to track CNS/ATM developments in industry and civil agencies, provide technical advice on DoD interests, and disseminate information to appropriate users. This tasking will require participation in technical standards development groups such as RTCA and AEEC. This requires both technical knowledge of the systems involved and the ability to recognize the potential cost and operational impact of proposed technical developments for DoD aircraft avionics. The GATO/MC² SPO will work with AFFSA and the Air Staff to work out roles and responsibilities regarding crossflow of information between the technical and policy sides of the process. The SPO also plans to establish a bridge to the MAJCOMS through its customer liaison office including on-site MAJCOM support.

Representatives of the GATO/MC2 SPO participate fairly regularly in RTCA SC-172, SC-186, SC-159, and sometimes SC-188 meetings, and in the AEEC HFDL, FMS, CMU, SAI, and CMU/VDR subcommittee meetings. Other DoD/Air Force representatives have occasionally attended various RTCA and AEEC meetings as well.

Each of these RTCA special committees and AEEC subcommittees typically holds three or four meetings a year. Clearly, to cover all of them would require a very large staff of dedicated travelers, and this is probably not practical. The load will have to be shared, and even then DoD will probably not be able to cover every meeting. However, it appears that very little changes from one meeting to the next, so it is probably sufficient to attend occasionally, as much for the networking aspects of the meetings as for the technical content.

7.3 PARTICIPATION IN AVIATION INDUSTRY GROUPS

In planning to equip its aircraft for CNS/ATM interoperability, the Air Force has many of the same concerns as the airlines and other aviation industry groups: regional divergence of requirements, slips in implementation schedules, and changes in direction by civil aviation authorities. We believe DoD can benefit from increased participation in these groups, and should attend their meetings, sit on their boards, and establish and maintain alliances with airline and other aviation industry groups as appropriate.

In the U.S., the Air Transport Association is the only trade organization for the principal U.S. airlines. In 1995 its 21 airline members accounted for 96 percent of the total revenue miles flown by U.S. carriers and 93 percent of the total cargo ton-miles. The Air Transport Association represents airline interests in Congress, to state legislatures, and to Federal agencies, including the FAA. International airlines are represented by the IATA,³ which is not recognized by ICAO but does have auditor status at ICAO meetings. IATA has six regional groups, which work with national CAAs, ICAO regional groups, and Eurocontrol. IATA participates with Eurocontrol and several airlines in the European ATM working group. The NBAA, a lobbying group for operators of business and commuter aircraft, also has many common concerns with DoD.

The National Defense Transportation Association (NDTA) is a government-industry association dealing with issues that affect the land, sea, and air components of defense transportation. Its members include the CRAF operators. A Delta Airlines Vice President for Flight Operations has written a letter to the Air Mobility Command proposing that the NDTA form a representative

³ A representative of one U.S. airline has commented to Air Force representatives that IATA is not very responsive to airline desires. We do not know whether this opinion is widespread.

committee to develop a plan for participation in CNS/ATM policy process. AMC is already addressing this issue by forming the GATM/CRAF working group, which had its first meeting in August 1997.

7.3.1 The Need for Situational Awareness

Although new CNS/ATM systems are many years in the making (some 15 years for RVSM, for example), in many cases new requirements are not incorporated into regulations until they are quite close to implementation. To further complicate decisionmaking, even long-held policies can change due to the availability of new technology or changes in administrative priorities. (Witness the fate of the Microwave Landing System.)

The DoD planning, programming, and budgeting system (PPBS) demands firm requirements documentation in order to compete for scarce funds. The *planning* phase of the PPBS begins about a year and a half in advance of the fiscal year in which the budget authority will be requested. It begins with review of National Military Strategy and continues through many steps in the Services, Joint Staff, OSD, Congress, and the White House until the funds are finally authorized and appropriated. It takes approximately 3 years to complete the remaining *planning* and *programming* phases until the funding is actually available as requested in the POM. New initiatives must be defended every step along the way with documented requirements and hard-hitting impacts if not funded. Due to funding constraints and aircraft usage requirements, most new programs are incrementally funded, thereby delaying planned aircraft modifications by years.

In a perfect world, DoD would be notified of upcoming CNS/ATM requirements several years in advance and given the opportunity to influence those requirements, which, once established, would not change. DoD would then have a firm basis for establishing its own requirements for new avionics in ample time to get them into the Federal budget process. In reality, this is not going to happen. DoD can and should continue to increase its influence at the CNS/ATM policy level, but there is a limit to how much we can expect from this process, particularly in dealing with (some) foreign CAAs and (some) regional planning groups, which are not always interested in what the U.S. Government (the FAA *or* DoD) wants. This means that DoD must also maintain and increase its awareness of proposed new CNS/ATM systems by continuing to monitor trends in civil aviation.

New CNS/ATM system requirements do not always have their origins at ICAO or even the CAAs, though eventually those bodies do have approval authority. Sometimes the technology is developed first and the ATC application for it is found later; an example is HFDDL technology, which was developed by Allied Signal under internal funding, tested by the airlines for company communications, and eventually proposed as an oceanic ATC datalink. Another example is VDL Mode 2, AVPAC, developed as an upgrade to ACARS for airline company communications; now that Mode 2 technology is available there is a push by the industry to use it for ATC communications as well.

In some cases the push to implement a new system comes from the grassroots level; an example is the FANS-1 implementation of CNS/ATM in the South Pacific. Regional CAAs, airlines, airframers (Boeing), and avionics vendors all worked together to implement FANS-1. Once FANS-1 avionics and ground systems became available, its use began spreading; currently some 22 airlines (600 aircraft) and 31 ground stations have or plan a FANS-1 capability. In this case, and others, interim solutions become de facto standards. A system that is available off the shelf and working has a big advantage in terms of airline acceptance over systems that exist only on

paper. A system for which the required ground infrastructure already exists has an even bigger advantage. Airlines dread spending money on avionics and then finding that promised benefits are not available because the supporting ground infrastructure is not there.

There are several indicators of the degree of reality of future requirements for avionics equipage: status of standards development or approval, vendor plans to develop and market a product that meets the requirement, airline plans to install the required equipment, and service provider plans to implement the necessary infrastructure and sell the services. Airlines do not buy new avionics unless they can prove a short-term return on investment or view them as mandatory. Vendors do not sink money into developing a new product—nor do service providers invest in ground infrastructure—unless they are convinced there will be a market. These trends are usually observable for some time before the planned requirements are actually implemented into regulations. Useful forums for tracking the development of new CNS/ATM systems include the FAA C/SOIT, mentioned above; various meetings of the civil aviation industry; the Boeing-sponsored CNS/ATM Focus Team, and the plentiful meetings of various technical standards development groups.

7.3.2 Recommendations

There is no mechanism in place to ensure two-way information flow between the DoD user community (MAJCOMS) and ICAO, regional planning groups, or the FAA on proposed new international policies, procedures, and system requirements that may have an impact on military operations. The formal link among DoD and ICAO, NATO, and the FAA ends at the DoD PBFA. A formal process must be put in place to ensure that DoD users are informed in a timely way of impending new requirements that may impact their operations, and that DoD user assessments of the impact that new proposals will have on their operations will be heard at appropriate levels at ICAO, NATO, and the FAA. The annual DoD/FAA planning meetings could be part of this process but must be given more direction and leadership if they are to do so.

Interactions with ICAO at the Council level will probably be most appropriate for dealing with broad policy issues but will not necessarily affect regional or national implementation plans. In recent years ICAO has increasingly allowed for regional approaches to CNS/ATM implementation. This is partly to take into account different regional needs but also to prevent issuance of unfunded mandates to countries that cannot afford to meet them.⁴

And even a victory at the policy level may be a hollow one. The FAA lobbied hard to get ICAO to endorse VDL Mode 3, TDMA, as the long-term solution to VHF frequency congestion and air-ground datalink, and succeeded. Despite this official ICAO endorsement, Europe has no plans for TDMA implementation and is pursuing instead a hybrid air-ground solution based on 8.33-kHz voice and multiple air-ground datalinks. In practice, the ICAO endorsement of TDMA appears to have had little effect worldwide except to allow the FAA to continue to pursue its (at that time) preferred solution for U.S. domestic airspace.

The best chance for DoD influence is likely at the regional navigation planning groups, official and informal, where actual planning and implementation are carried out. DoD must increase its

⁴ If ICAO member states implement a system for which SARPs have been adopted, they must ensure that the system complies with the applicable SARPs. However, they are not required to implement a new system just because SARPs have been adopted. There are SARPs for protected ILS, for example, but they are expected to be implemented only in Europe where VHF broadcast interference is a problem.

participation in these groups, and participate regularly. The most important groups are IPACG, which is planning for implementation of RVSM, RNP, and oceanic datalink in the North and Central Pacific; NATSPG, which is planning for expansion of RVSM and implementation of RNP and oceanic datalink in the North Atlantic; and EANPG, which is planning for implementation of RVSM, 8.33-kHz VHF voice, protected ILS, BRNAV, Mode S, and other systems in European airspace. To further increase DoD influence in European airspace issues, we should support ICAO recognition of NATO.

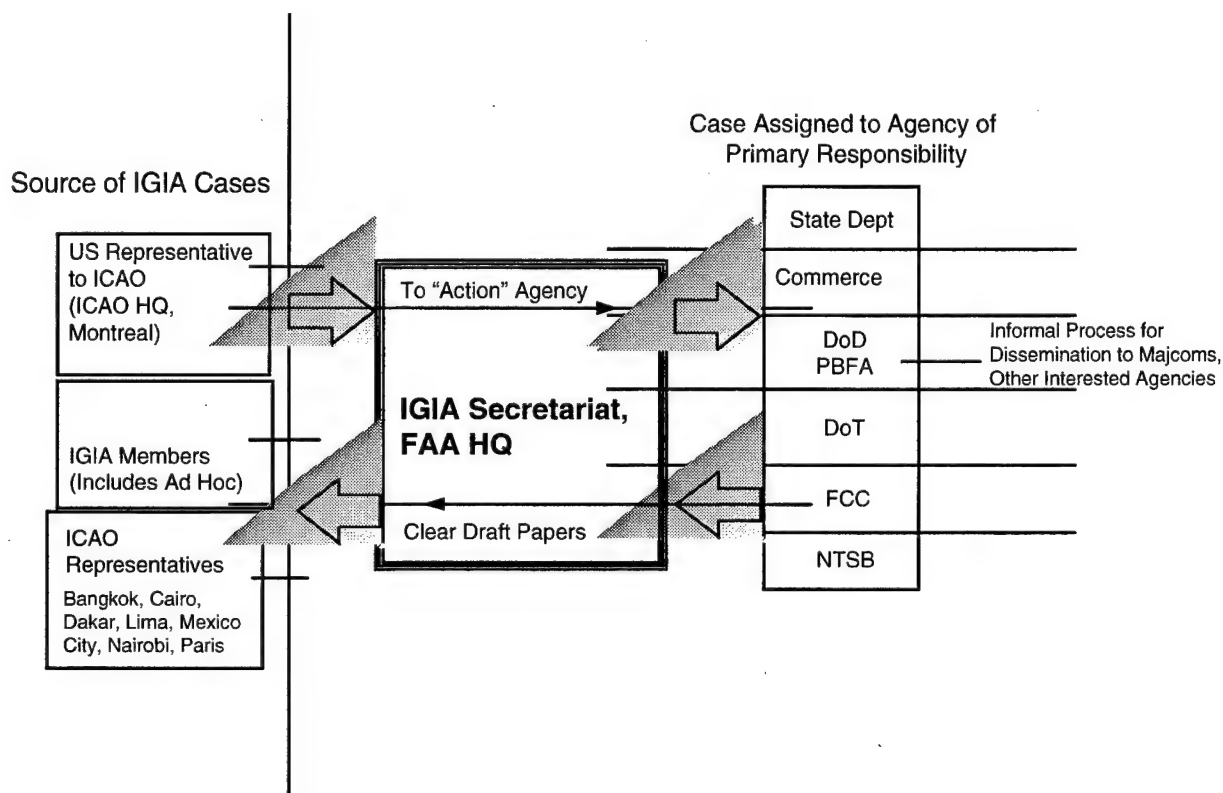


Figure 4. *Interagency Group on International Aviation Coordination Process*

Chapter 8—Ground Infrastructure

8.1 ATC GROUND INFRASTRUCTURE

The Air Force maintains an ATC capability to support Global Reach—Global Power objectives and operates fixed-base ATC facilities to ensure that a cadre of qualified personnel is available for rapid deployment to provide for the safe, orderly, and expeditious launch and recovery of aircraft in a combat or contingency environment.

The systems currently fielded by the Air Force, the other Services and the FAA to provide ATC services have reached the end of their life cycle. Additional emerging technology will allow all U.S. ATC service providers to gain cost benefits and operational utility by transitioning from analog to digital. This transition is being addressed, in part, by a joint-Service, Air Force—led modernization program; as currently funded, it will provide DoD with the opportunity to acquire state-of-the-art systems from the FAA or through Air Force contracts.

Systems identified for procurement include digital airport surveillance radars, a digital automation system, digital communications switches, and a computer-based scheduling system for SUA. This program is approaching a Milestone III decision, with the first acquisition scheduled for FY98.

The modernization program was initially sized to replace the listed systems at the DoD approach control locations. Because of schedule slips, program cancellations, and emerging technologies, the Services, including the Air Force, are expanding the program to include all CONUS and outside-CONUS (OCONUS) sites. This will result in a reduced logistic support stream, realize the economics of bulk acquisition, provide equipment commonality for controllers and maintenance personnel, and assure seamless interoperability between the Services and the FAA.

In the tactical area, the Air Force and the Marine Corps are modernizing their systems component by component. Some of their modernization initiatives are being pursued in a partnership; others are being pursued as individual Service initiatives. The Navy's tactical systems are employed on air-capable ships. The major acquisition initiative in this area is the development of an automation system like that deployed on big-deck carriers to support flight operations on amphibious warfare ships. Another modernization initiative is the development and deployment of the next-generation IFF interrogator system. When completed, it will have utility for all vessels regardless of class and may be capable of use ashore if the Navy retains equipment commonality between its shore and sea systems.

ATCALS provide the operational conduit for all contingency operations or war. During Operations Desert Shield and Desert Storm, the Air Force deployed seven RAPCONs, two ATCTs, seven NAVAIDs, and 330 personnel to manage the deployment and redeployment of combat forces as well as the daily ATC operations. Air Force personnel also augmented host nation staffing of ATC facilities in-theater. The overwhelming success of the air campaign can be attributed directly to the well-trained, dedicated men and women in the ATC career field and to our deployable ATCALS.

The Air Force operates fixed-base RAPCONs to maintain a cadre of qualified personnel to deploy to forward locations and support combat operations. Air Force MAJCOMS determine the appropriate location for these facilities by assessing unit requirements. In addition, the Air Force operates fixed-base ATCTs, navigation, and approach aids at bases throughout the world.

Whether in combat or stateside, the Air Force furnishes the same ATC services and follows the same ATC procedures as host nations' civil agencies. In the United States, the FAA delegates management of airspace to the Air Force when that is mutually beneficial for the effective use of airspace. The Air Force, in turn, agrees to provide the same level of service as the FAA to both civil and military aircraft. Air Force ATC facilities in host nations operate in the same manner. The equivalent level of service provided from FAA, host nation, and Air Force ATC facilities permits the ATC system to be "transparent to the user," meaning that any aircraft uses the same procedures regardless of who provides the service. To provide equivalent, transparent service, both deployable and fixed-base ATC systems must be interoperable, or capable of exchanging aircraft position and flight plan information with adjacent systems, both foreign and domestic. Additionally, the Air Force must maintain some residual capability to operate in an environment in which our access to satellite-based navigation systems is restricted, degraded, or denied by enemy action.

The future ATC environment in which the Air Force must operate is experiencing the greatest change since surveillance radar for ATC was introduced in the 1950s. The worldwide ATM structure is evolving from a ground-based analog to a space-based digital system. The Air Force plan to upgrade or replace outdated and hard-to-maintain equipment is documented in its Air Traffic Management Strategic Plan. The plan identifies:

- The national military strategy that determines the need for fixed-base and deployable ATCALS
- ICAO and Federal requirements that affect fixed-base and deployable ATCALS
- Deficiencies in the ability of ATCALS to meet current requirements
- Deficiencies in the ability of ATCALS to meet future requirements
- Future avionics capabilities
- Deficiencies in the controller training infrastructure
- Current and future plans to solve ATCALS and training deficiencies

The following reflects a brief description of key ground elements and issues in the plan:

- **Currently deployable ATCALS** are manpower intensive to set up and operate, and require extensive airlift to move—deficiencies that have delayed deployment of U.S. forces. With modifications and additional funding, most current systems can be sustained until 2005. However, combat operational capability could be at risk because no programs exist to ensure deployable ATCALS interface with future ATC and theater battle management (TBM) systems. AFFSA will work with the MAJCOMS to define deployable ATCALS and funding requirements.
- **Terminal control RAPCON and ATCT deficiencies** are identified and will be corrected through the DoD NAS Modernization Program, currently in Phase II of acquisition. Through this initiative, the Air Force, Army, and Navy are procuring new communication, automation/display, and surveillance systems in a joint venture with the FAA. Current Air Force program funding addresses most CONUS RAPCONs as well as ATCTs collocated with RAPCONs. Even though a Milestone I and II cost and operational effectiveness analysis (COEA) determined that life-cycle costs are reduced by purchasing new equipment for the entire system, there is no funding identified for some CONUS or OCONUS facilities.
- **Precision approach services** are moving toward space-based technologies, especially in the civil community. DoD is examining whether this move provides the best solution for a universal precision approach capability that is interoperable among the Services. In August 1995, the JROC validated the need for a deployable, reliable, survivable, maintainable, jam-resistant, and interoperable

precision approach capability. The Air Force, Navy, and Army are evaluating future systems through the JPALS Program. The first phase of the evaluation—Phase 0 concept exploration (AoA)—identified augmented GPS as the most promising alternative to satisfy the Services' future precision approach and landing requirements. However, the AoA also identified risk areas (GPS vulnerability) and architecture issues (avionics integration and tactical/shipboard system configurations) that still need to be addressed before a final decision is made; these issues will be addressed in a 3-year Architecture Requirements Definition (already fully funded) from FY99 through FY01. A JPALS Milestone decision is scheduled for early FY02. JPALS funding requirements beyond FY01 are dependent on the Architecture Requirements Definition results and will be addressed in future Service funding requests.

- **Controller training issues** are being addressed through nonmateriel and materiel means. Training programs are being updated to ensure that all controllers graduate from the ATC Tech School with required proficiency levels. State-of-the-art simulators are required to increase controller proficiency levels, crew resource management, and flight safety. A study of ways to improve the RAPCON simulator is under way, and an initiative for an ATCT simulator is nearing its Milestone I review. Both the RAPCON and ATCT simulators require funding.

8.2 GATM INFRASTRUCTURE REQUIREMENTS

The GATM requirements are geographic, time-phased, and evolving. As a result, there has been a proliferation of both aircraft and ground infrastructure upgrade requirements to maintain access to the global aviation environment (Figure 5). The aviation community is migrating to a space-based navigation system to provide the RNP, and robust datalink and voice communications to provide the RCP (Figure 6). However, the rapid evolution of information technology provides an opportunity to address current deficiencies in different ways and shape the future of ATM. The Air Force is building a robust Global Grid to provide worldwide connectivity, sharing of data, and a common picture of the environment (Figure 7). The same capabilities are key ingredients of the emerging future ATC systems. With proactive DoD participation in the civil aviation process, DoD can leverage its planned C² investments to meet the emerging GATM requirements and improve its C² capabilities.

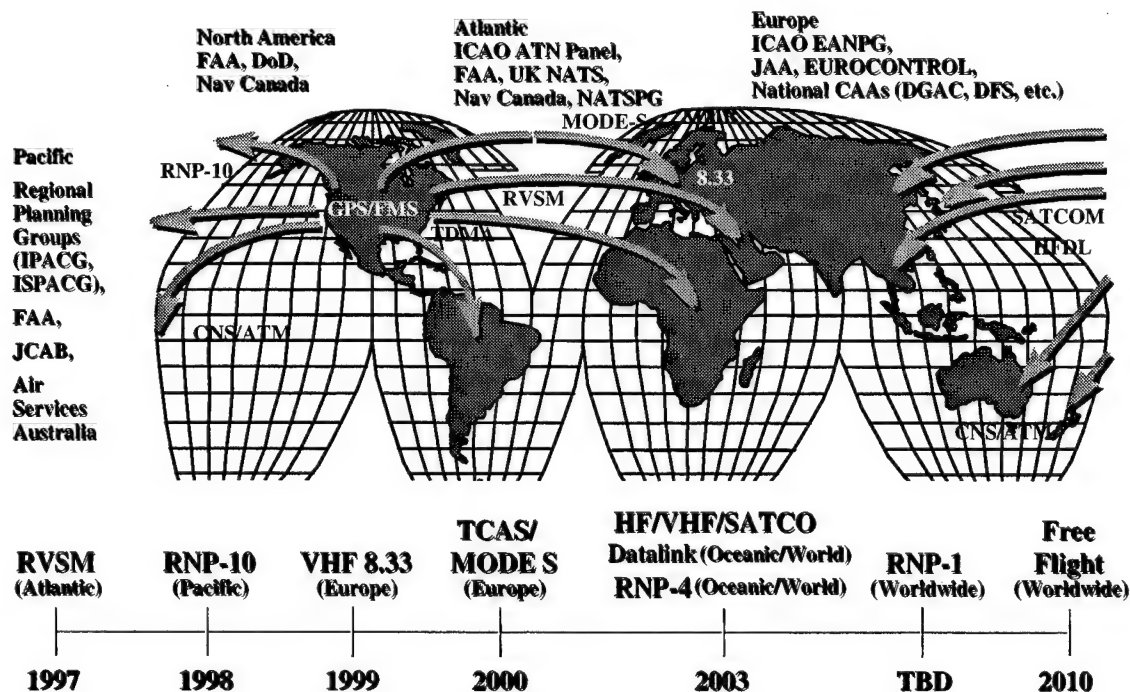


Figure 5. Aviation Controlling Bodies (a geographic, time-phased, evolving program)

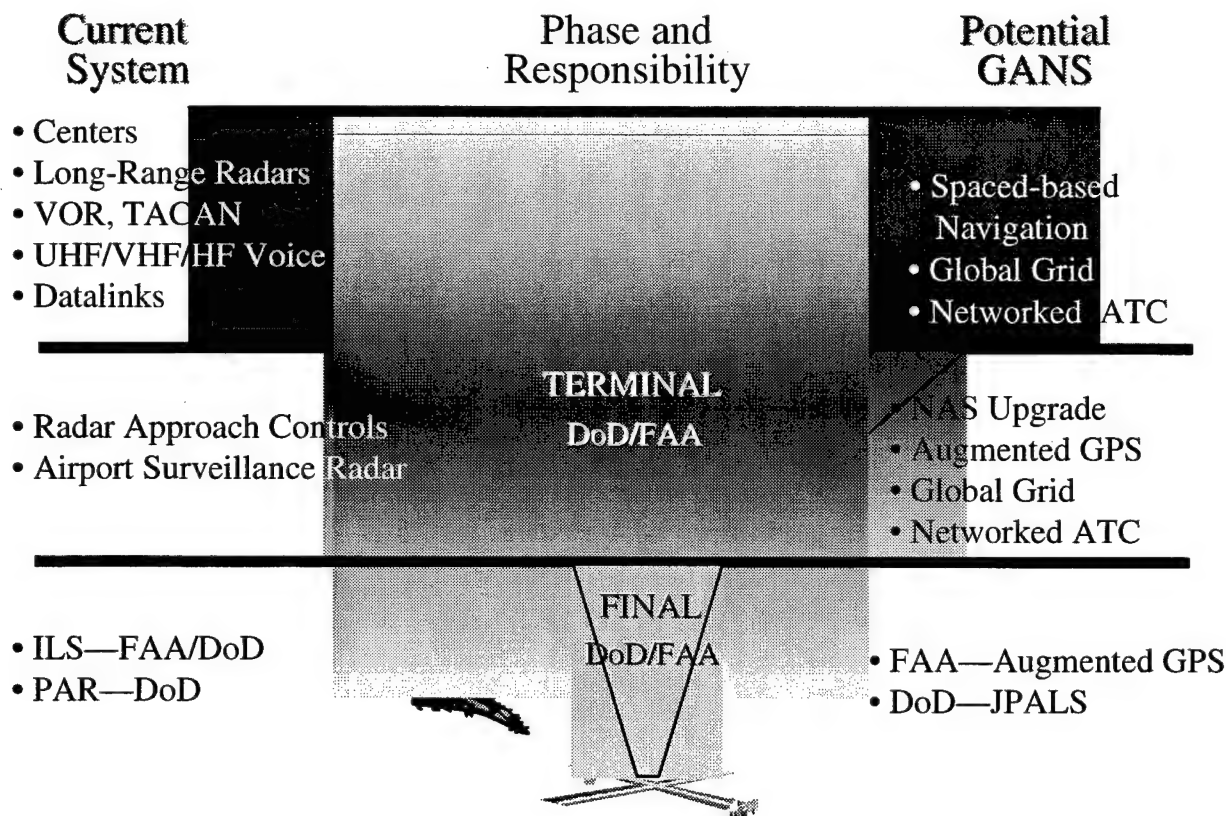


Figure 6. Operational Air Traffic Environment

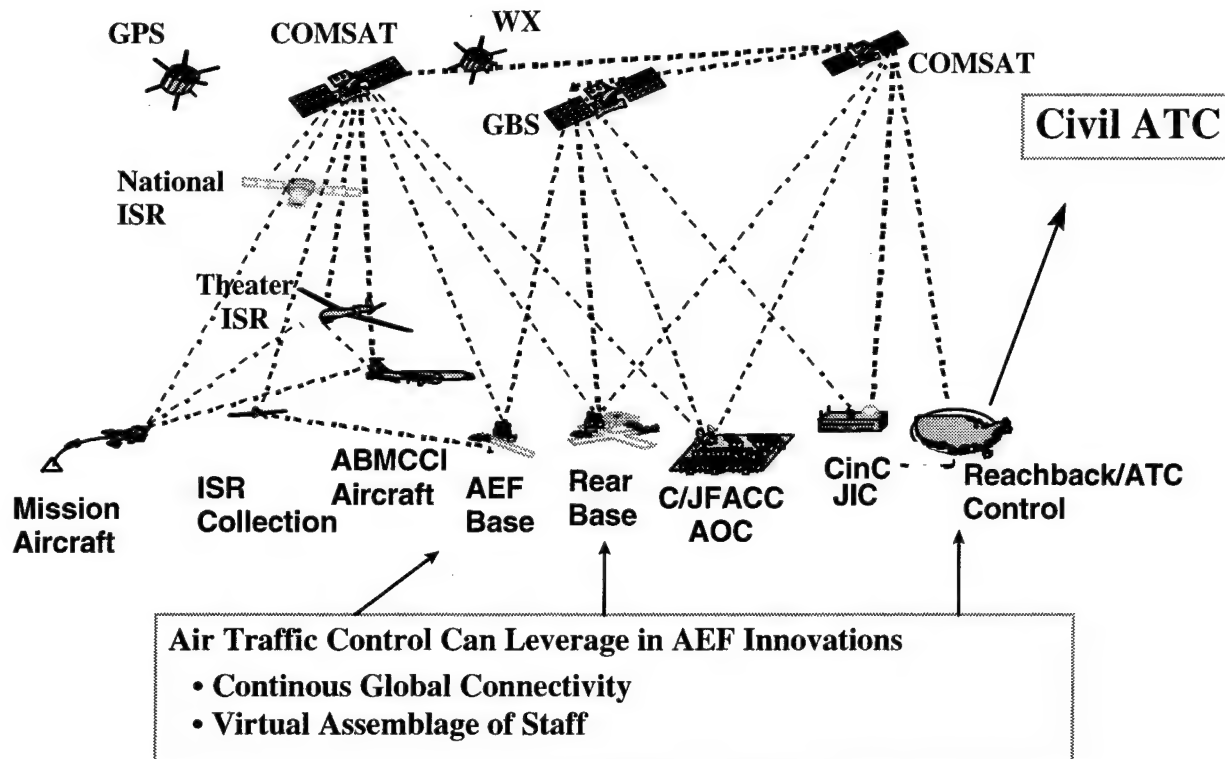


Figure 7. Network ATC Concept Visualization

A key premise of the network ATC vision is to enable GATM compliance without extensive aircraft modifications by considering enhancing ATC and Global Grid infrastructure instead of aircraft where appropriate benefits can be realized. The key components of this strategy are successful implementation of spaced-based navigation systems to meet both en route and landing RNP and a Global Grid that can meet the RCP. The Global Grid, data fusion, and automated data-processing equipment required to implement this are the same or complement the components required for air expeditionary forces (AEFs) and other military C². Merging the GATM RCP into the DoD's Global Grid, data fusion, and automated data-processing equipment provides synergy and the opportunity to more effectively meet both the AEF and GANS vision by allowing any platform with one or more communications devices that meet these standards to enter the Grid with a piece of information and have any other platform be able to accept that information in any other of the communications devices that meets those standards.

By effectively implementing these ATC capabilities within the military and civil global grids, there are numerous operational benefits. In-transit visibility can be obtained with satellite reporting of a GPS-aided position. With data fusion of reported navigation data and robust network communications, en route and terminal ATC can be performed remotely. For example, in an AEF deployment the RAPCON could remain at Aviano and control operations at Tusla, reducing the deployment footprint. With network switching, communications could be accomplished on any radio vice specific geographic radio requirements.

The key to implementation is an expanded leadership role by DoD. The Air Force needs to energize its partnership with the FAA/ICAO. RTCA has responsibility to the FAA to define the required CNS performance for the future airspace environment. The RNP work is complete, and

ICAO has developed an RNP manual for application of the RNP concept to airspace management. The RCP work has not yet started, and the Air Force Aerospace Command and Control Intelligence, Surveillance, and Reconnaissance Center (AC²ISRC) can make an important contribution to this document and also pave the way toward the larger Global Grid that embraces both the FAA/ICAO ATC vision and the DoD's C² vision.

8.3 AIR TRAFFIC CONTROL GROUND INFRASTRUCTURE

8.3.1 Mission

The Air Force maintains an ATC capability to support Global Reach–Global Power objectives, operating fixed-base ATC facilities to ensure that a cadre of qualified personnel is available to rapidly deploy to provide for the safe, orderly, and expeditious launch and recovery of aircraft in a combat or contingency environment. The Air Force MAJCOMS determine the appropriate location for these facilities. Whenever tasked, the Air Force must be ready to project its ATC capability to enhance the effectiveness of contingency and/or wartime operations by furnishing services to U.S. and allied aircraft from deployable ATCALS. This section of the report highlights:

- A background on ATC services and Air Force ATCALS
- A functional area assessment of ATCALS
- A description of current ATCALS and known deficiencies
- A description of ATC training infrastructure and known deficiencies

8.3.2 Background

In the United States, the FAA is the single manager of the NAS. Established by the Federal Aviation Act of 1958 (Public Law 85-726), the FAA is responsible to provide for the safe and efficient use of the navigable airspace. The FAA accomplishes this mission by furnishing separation, sequencing, navigation, and approach-to-landing services to civil and military aircraft. DoD provides the same ATC services for civil and military aircraft from fixed bases throughout the country. In fact, the DoD facilities provide approximately 20 percent of our nation's ATC services from facilities operated by the Air Force, Navy, Marine Corps, and Army. (The Air Force contribution is about 10 percent.)

The Federal Aviation Act of 1958 directs DoD and the FAA to provide a common civil-military ATC system. Facilities operated by DoD are required to provide the same or "equivalent service" and follow the same procedures as their civil counterparts.

The requirement to provide equivalent service also applies to Air Force ATC facilities in host nations. The goal is for the international ATC system to be transparent to the user, meaning that military aircraft do not require different equipment to receive ATC services from a civil facility and vice versa.

Besides the requirement to provide transparent service, ATC systems must be capable of exchanging aircraft position and flight plan information with adjacent systems. This level of interoperability is needed to ensure that Air Force or other aircraft under DoD control can enter FAA or host nation–controlled airspace without delays or problems.

The Air Force negotiates and outlines its fixed-base ATC infrastructure in agreements between DoD and the FAA as well as with host nations. To define this infrastructure, the Air Force

determines the number and location of facilities needed to ensure that controllers are trained and available to deploy in support of actions directed by the Joint Chiefs of Staff (JCS). The Air Force then asks the agency responsible for controlling a nation's airspace (like the FAA) to delegate airspace in which the Air Force will provide ATC services. Once airspace has been delegated:

- The Air Force accepts responsibility to provide ATC services and must operate a facility and staff to provide the same service as the FAA or host nation would have provided.
- The Air Force must continue to furnish the same level of service as the FAA or host nation would have provided when controllers deploy to support contingency and/or wartime operations. Thus, the Air Force must staff facilities to provide the required service before and during a deployment of personnel.

All the MAJCOMS have ATC components. At Air Force bases throughout the world, MAJCOMS operate and maintain navigation and precision approach and landing systems, which are required for an all-weather operational capability. MAJCOMS also operate control towers from which air traffic controllers provide separation and sequencing instructions to aircraft operating in the immediate airspace surrounding a base. Finally, MAJCOMS operate radar systems, including RAPCONs and ground-controlled approach facilities, from which air traffic controllers provide separation and sequencing instructions to aircraft operating in airspace that is delegated to the Air Force by the FAA or host nations. The Air Force bases its RAPCON requirements on its deployable commitments. To define RAPCON requirements, the Air Force determines the number of controllers needed to comply with Defense Planning Guidance (DPG) and the number of radar facilities needed to ensure that the controllers are proficient in ATC operations. Since an Air Force RAPCON cannot close when controllers deploy, total controller staffing exceeds deployable controller requirements. Once the total controller force is determined, the MAJCOMS assess their requirements and determine the most appropriate locations for RAPCONs.

ATCALS consist of:

- Automation systems to process and display aircraft position, flight plan, and information about hazards to controllers
- Surveillance systems to provide aircraft position and weather information
- Communication systems to permit the transfer of information between controllers and aircrews and between adjacent ATC facilities
- Navigation/approach-to-landing aids that provide aircraft with position information
- Personnel to operate and maintain the systems described

Today's Air Force ATCALS comprise a mix of equipment and worldwide ATC staffing just under 4,000 personnel. Table 6 defines the ATCALS functional areas and gives examples of systems used.

Table 6. ATCALs Functional Areas and Systems

Functional Areas	Ground System(s)	Avionics
Deployable Systems	Mobile Tower/Radar/ TACAN/PAR/MLS/Comm	TACAN/MLS/Comm
Terminal Control	Primary/Secondary Radar/ ATC Simulation/Comm	IFF/Comm
Navigation and Approach	TACAN/VOR/NDB ILS/PAR/Comm	TACAN/VOR/NDB ILS/MLS/Comm

TACAN: Tactical Air Navigation

VOR: Very High Frequency Omnidirectional Range

IFF: Identification, Friend or Foe

ILS: Instrument Landing System

NDB: Nondirectional Beacon

PAR: Precision Approach Radar

MLS: Microwave Landing System

8.3.3 ATCALs Functional Area Assessment

The Air Force bases its current ATCALs infrastructure and personnel requirements on the DPG requirement to maintain a capability to fight two nearly simultaneous MRCs. The Air Force, in turn, provides guidance for the ATCALs deployment strategy in a Program Guidance Letter (PGL), *Air Force Deployable ATCALs Missions*.

Although ATCALs exist to support contingency and wartime operations, they must also be capable of providing the same services provided in host nations, and interface with host nation ATM systems. Consequently, other DoD and non-DoD directives, such as the FRP, the NAS System Requirements Specifications, FARs, and host nation directives, also affect ATCALs. Thus, an assessment of ATC requirements cannot be accomplished by evaluating only Air Force requirements.

ATCALs provide information used by controllers and aircrews to ensure that aircraft operate and navigate safely and efficiently. Since ATCALs provide information, ATCALs tasks equate to the provision of varying types of information needed by controllers and aircrews to perform their duties. For example, controllers separate aircraft from one another by understanding the traffic situation and communicating instructions to pilots, who maneuver their aircraft accordingly.

With some exceptions, most ATCALs perform the tasks required. However, today's systems are either no longer cost-beneficial to operate or do not provide information in the manner prescribed by the FAA and/or ICAO (for example, datalink communications). Furthermore, many do not interface with adjacent ATC facilities; this may result in operational delays that impact the Air Force's combat force projection capabilities.

8.3.3.1 The ATM Environment

The world's ATM infrastructure is entering a period of the greatest change since surveillance radar first entered the ATC system in the 1950s. This transition is driven by continual increases in domestic and international air traffic, emerging CNS technologies, and competitive pressures

for financial resources. The future Air Force deployable and fixed-base ATC infrastructure must operate within this new environment.

The present ATM system is bound by the capabilities of CNS equipment that, in many cases, uses 40-year-old technologies. Outdated systems constrain capacity and efficiency. For example, aircraft separation standards are based on the inability to precisely determine and notify a controller of an aircraft's position. New technologies such as the GPS with WAAS corrections and datalink communications will be used to provide accurate position information. The improved position determination capability and the ability to efficiently relay this information to air traffic controllers will facilitate a reduction in separation standards, with a corresponding increase in airspace capacity.

In October 1992, ICAO endorsed a strategic action plan designed to provide a framework for the priorities of the organization into the next century. ICAO's FANS committee went on to define the plan that would transition the international aviation system from the current ground-based CNS infrastructure to a satellite-based system. This infrastructure would furnish ATC service providers and aircrews with information to enhance system efficiency worldwide.

Evolution in the ATM system will affect DoD and the Air Force. As a provider of ATC services, DoD must update or replace outdated systems to furnish the same capabilities as civil authorities in the United States and host nations. New systems will also reduce operations and maintenance costs.

As a user of ATC services, DoD must upgrade avionics in order to retain unrestricted access to domestic and international airspace. New avionics will also permit DoD to realize the efficiencies associated with the future system. However, procuring the ground and avionics systems necessary to fully implement the capabilities available through new CNS technologies will require a significant investment.

Even with the dramatic changes under way, the Air Force must maintain a residual capability to provide ATM services from fixed and deployable ground-based systems. The planned migration to new systems may be delayed or abandoned. Furthermore, the Air Force must maintain the ability to operate in a combat environment where access to space-based systems may be restricted, degraded, or denied.

8.3.3.2 The Current Domestic ATM Environment

Like the ATM systems operated by host nations, our current domestic ATM system is based on the ground-based control of air traffic. Primary and secondary radar systems scan the airspace and provide air traffic controllers with information on aircraft position; the information is used to separate and sequence aircraft. Aircraft navigate using ground-based aids such as VOR collocated with TACAN. Aircraft execute approaches to landing using ILSs that provide aircraft systems with localizer and glide slope information over VHF and UHF frequencies. Precision approach radar may also be used by controllers to provide aircrews with approach path information. Figure 8 depicts the current domestic ATM environment.

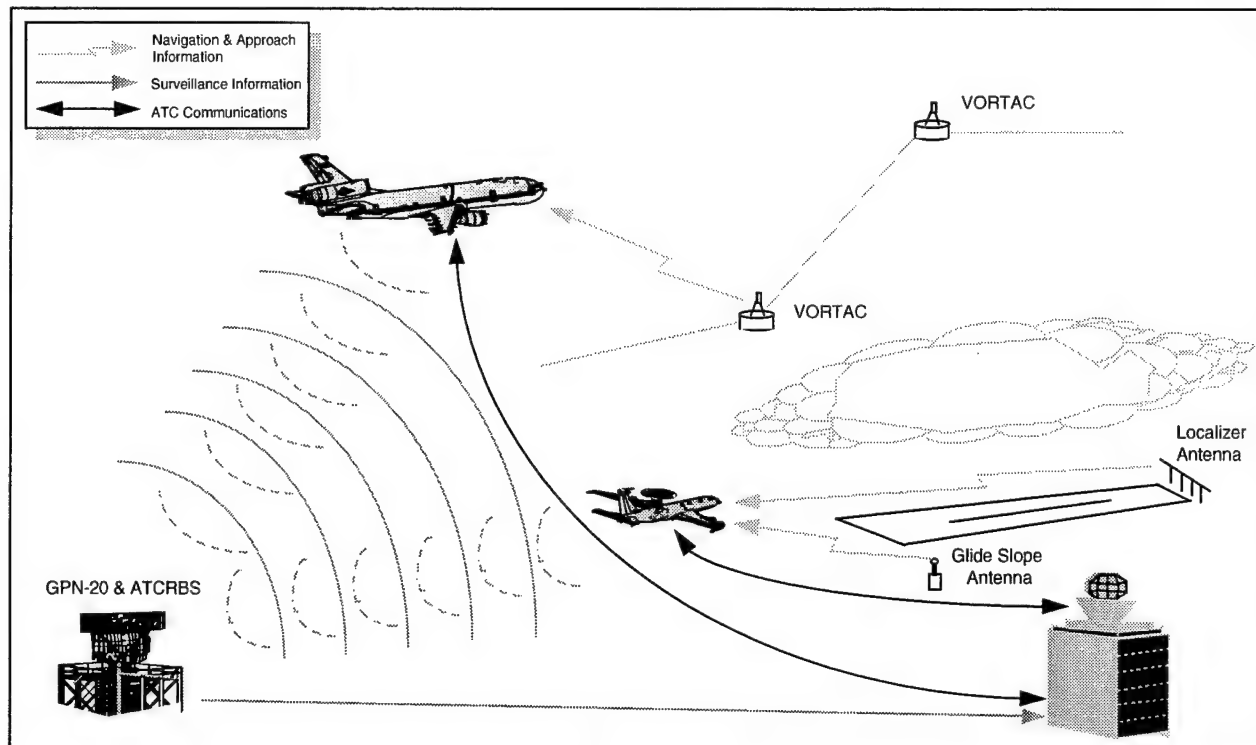


Figure 8. Current Domestic ATM Environment

8.3.3.3 The Current Oceanic ATM Environment

In oceanic airspace, ground systems cannot provide the necessary surveillance and navigation information. Also, VHF and UHF radios with line-of-sight range cannot be used to exchange information between air traffic controllers and aircrews. Aircrews must report their estimated positions over HF radio with no line-of-sight limitations. Unfortunately, HF can be an unreliable communications medium. Furthermore, air traffic controllers and aircrews must communicate through an HF radio operator, further delaying position report updates. Since the oceanic ATM system cannot precisely determine actual aircraft positions, ATC uses generous spacing between aircraft to ensure safety, but this practice limits airspace capacity. Figure 9 depicts the current oceanic ATM environment.

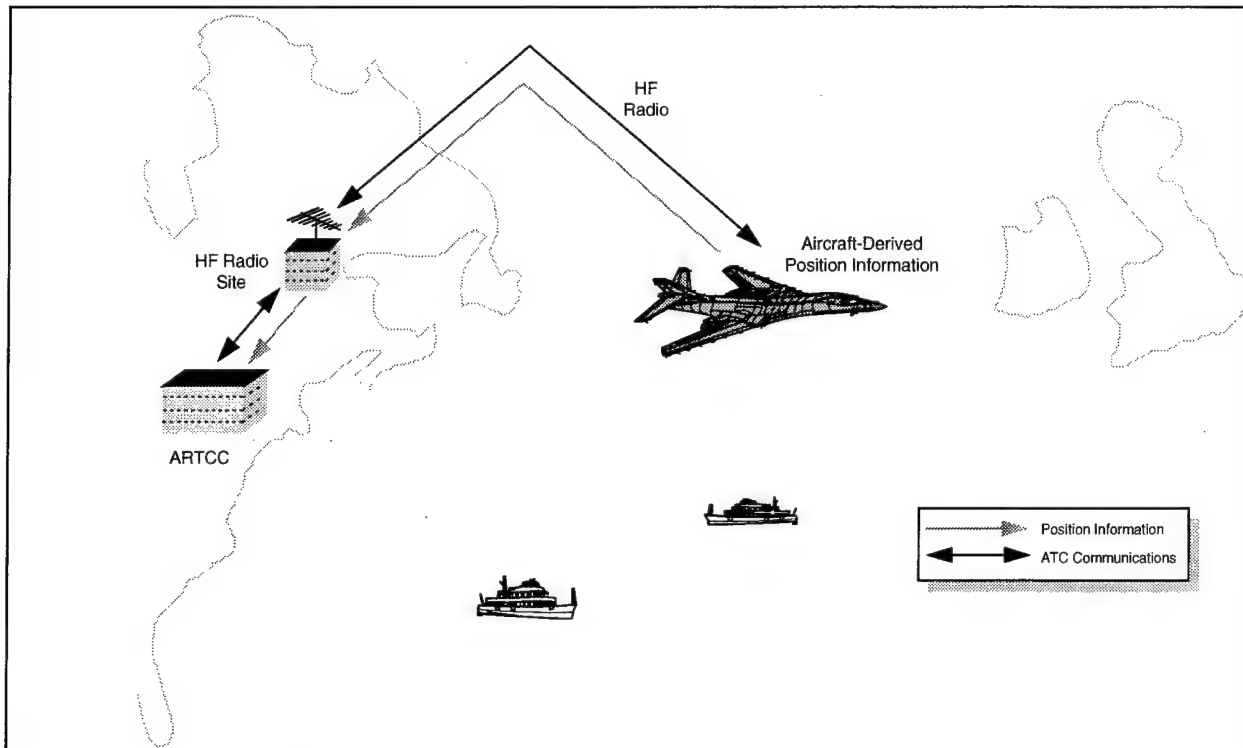


Figure 9. Current Oceanic ATM Environment

8.3.4 Concept of Operations

The HQ USAF PGL dated 20 December 1993, *Air Force Deployable ATCALS* and the draft revision *Organization of Air Force Deployable Command, Control, Communication, and Computers (C⁴) and ATCALS Force Structure*, defines three categories for ATCALS deployment, which are defined as follows:

- **Initial deployment** begins when combat control teams or special tactics teams secure and establish an airdrome to receive aircraft using small, lightweight communications equipment. Initial services will include visual flight rules ATC services followed by limited IFR services using deployable TACAN equipment.
- Within 5 to 15 days, **follow-on deployment** begins, which includes the arrival of ATCALS packages that provide the communications capability necessary to interface and/or establish a capability to support squadron flying operations. The Theater Air Base (TAB) package augments initial communications packages to expand communications capability to operate as a bare base until permanent communications are installed. A TAB package consists of base communications systems, theater connectivity, and ATCALS.
- **Sustaining deployment** requires ATCALS packages that provide required IFR capability up to and including dual-runway precision approach capability. These packages also ensure a stable theater ATC system to support wing flying operations.

Deployable ATCALS are maintained in active combat communications and Air National Guard (ANG) units to support contingency missions assigned by the JCS and defined in war plans. When deployed, they are assigned to the appropriate Air Force Component Commander. Fixed-

base systems, located at air bases and auxiliary airfields, are an integral part of the NAS and provide routine ATC services. These systems also allow controllers to remain proficient in ATC procedures for contingencies and wartime operations.

Under current employment philosophy, personnel to operate and maintain the deployable ATC capability are drawn from ANG and fixed-base resources.

At fixed bases, controllers play a major role in the daily operations of local flying organizations. Air traffic controllers are responsible for all air traffic movement within the airspace, and on the runways or taxiways assigned to the base.

8.3.4.1 Deployable Air Traffic Controllers

In August 1995, the Air Force conducted a review of wartime staffing requirements. According to this analysis, 660 controllers and 192 airfield management specialists are needed to support two MRCs. Figure 10 depicts the August 1995 wartime personnel requirements.

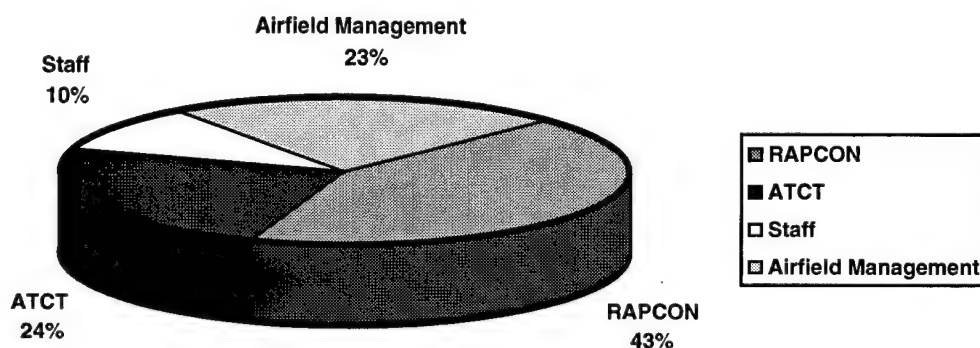


Figure 10. Wartime Personnel Requirements

8.3.4.2 Deployable Systems

The deployable ATCALS infrastructure consists of the AN/TPN-19 Landing Control Central with ASR, precision approach radar (PAR), and operations center; AN/MPN-14K Landing Control Central with ASR, PAR, and operations center; AN/TRN-26 or AN/TRN-41 TACAN; AN/TRN-45 Mobile Microwave Landing System (MMLS); and the TSW-7 Control Tower or AN/MSN-7 Tower Restoral Vehicle.

It is envisioned that ground-based deployable systems will be required to support combat forces as least through the first decade of the 21st century. Therefore, continued attention to the modernization, sustainment, and replacement of ground-based deployable systems is required to ensure adequate combat support capability. As Table 7 indicates, many of today's deployable systems were fielded before 1980.

Table 7. Deployable Systems

<i>Item</i>	<i>IOC/FOC</i>	<i>Quantity</i>
TPN-19 RAPCON	1979/1985	10
MPN-14K RAPCON	1980s	16
TRN-26 TACAN	1971/1972	43
TRN-41 TACAN	1978/1980	63
TRN-45 MMLS	1996	33 + 4 spares
TSW-7 Tower	1968/1973	22
MSN-7 Tower (TRV)	1996/1997	19

8.3.4.3 Terminal Control Systems

The Air Force operates ATC facilities at locations where the nature of the local mission dictates that the Air Force is better suited to provide ATC services than a civil or host nation agency. The terminal control force structure consists of ground-based radar surveillance systems, which include the GPN-12 and 20 primary radars along with SSR. Also included are control towers and radar facilities (RAPCONs and GCAs). Table 8 outlines the terminal control force structure.

Table 8. Terminal Control Force Structure

<i>Item</i>	<i>IOC/FOC</i>	<i>Quantity</i>
GPN-12 Radar	1975/1980	15
GPN-20 Radar	1979/1988	31
SSR	1970s	47
Comm Switch	1970/1987	129
Automation Systems	1980	35
Control Towers	N/A	99
RAPCONs	N/A	37
GCAs	N/A	7

8.3.4.4 Navigation Systems

Navigation and approach systems include ground-based systems that provide information used by aircrews to navigate and execute approaches to landing. Navigation and approach aids consist of TACAN, VOR, VORTAC (VOR and TACAN collocated within the same facility), and NDB systems. All are ground-based aids that provide azimuth information, with TACAN and VORTAC providing distance information as well. Table 9 defines the current ATCALS navigation and approach aid force structure.

Table 9. Navigation and Approach Aid Force Structure

<i>Item</i>	<i>IOC/FOC</i>	<i>Quantity</i>
GRN-19 TACAN	1950s	6
GRN-20 TACAN	1950s	7
FRN-45 TACAN	1987/1996	72
FRN-44 VOR	1987/1994	9
FRN-43 VORTAC	1987/1994	24
URN-5 NDB	1955/1958	23

8.3.4.5 Precision Approach and Landing Systems

PALS consist of ILS and PAR systems. ILSs transmit lateral and vertical guidance signals to aircraft; these signals are used to determine an aircraft's position with respect to a predetermined approach path. PAR provides precise aircraft position information to controllers. Controllers interpret this information, determine appropriate maneuvers to keep an aircraft aligned with the precision approach path, and transmit instructions to pilots via VHF and/or UHF radio. Based on the information provided by ILS displays in the aircraft or PAR controller instructions, aircrews or aircraft systems alter aircraft trajectory to proceed on a precise path to landing. Table 10 defines the current precision approach aid force structure.

Table 10. Precision Approach and Landing Systems Force Structure

<i>Item</i>	<i>IOC/FOC</i>	<i>Quantity</i>
GRN-29 ILS	1979/1993	150
FPN-62 PAR	1975/1978	19
GPN-22 PAR	1978/1985	14

8.3.5 Deployable Systems

Deployable ATCALS include mobile RAPCONs, control towers, navigation systems, and PALS. With the exception of the MMLS, all of the deployable ATCALS described were fielded before the 1980s. Due to their age and dated technology, the deployable ATC equipment will soon be unable to support Global Reach and TBM force employment strategies. Furthermore, they require excessive airlift resources to deploy, do not interface with digital C⁴ architectures, and cannot be integrated into regional terminal and en route ATC system architectures. There are currently no umbrella programs to modernize deployable ATC systems.

8.3.5.1 Mobile RAPCONs

The TPN-19 Landing Control Central System is the deployable RAPCON operated by Air Force active-duty forces. The TPN-19 provides a complete approach control and precision approach capability, but there are a number of deficiencies associated with the TPN-19: Shelters for all system components leak and require repair; the TPN-25 PAR does not have a redundant transmit-and-receive capability and is frequently unavailable for use; the operations center's displays and

communications switch are economically unsupportable; finally, the microwave connectivity between the surveillance radar and the operations center is unsupportable, and the interim remedy is cumbersome and time consuming to deploy. Only the problem of leaking shelters is being addressed by an approved modification. The rest are unfunded requirements. The life expectancy of the TPN-19 (with all modifications) is to 2010. Without modifications, the system may be lucky to reach 2005.

TPN-19 deficiencies lead to delays and avoidable restrictions. Lack of TPN-19 PAR redundancy results in combat aircraft diversions. This increases aircraft regeneration time.

The MPN-14K system is the deployable RAPCON used by the ANG. It consists of a surveillance radar, PAR, and an operations and maintenance van. Like the TPN-19, the MPN-14K provides a complete approach control and precision approach capability. The MPN-14K also suffers from a number of deficiencies: The system cannot be transported on C-141 aircraft because the MPN-14K skids do not align with C-141 pallet rollers; it cannot support dual-runway operations, a requirement defined in HQ USAF program guidance; it contains logistically unsupportable displays and communications switching subsystems. The MPN-14K deficiencies have been identified for corrective action; none of the modifications are funded. The life expectancy of the MPN-14K is questionable without the improvement.

MPN-14K deficiencies inhibit the ANG from meeting its deployable commitments.

8.3.5.2 Deployable TACAN

Deployable TACANs are generally the first assets deployed during contingency or wartime operations and include the TRN-26 and -41. Use of the TRN-41 is preferred because of its reduced size, weight, setup time, power consumption, and maintenance costs. The TRN-26 TACAN will be sustained until a modification to the TRN-41, enabling the system for IFR operations, is completed in 1998. The mobile TACAN is expected to remain in the Air Force inventory until the full transition to GPS for navigation is complete.

8.3.5.3 Deployable Air Traffic Control Tower

The TSW-7 mobile tower is being replaced by the MSN-7, a self-propelled control tower, through an acquisition program to be completed in 1998. The MSN-7 will include improved communications, recording, and weather-sensing equipment.

8.3.5.4 Mobile Microwave Landing System

MMLS provides a mobile precision approach capability for austere and tactical locations. All AN/TRN-45 MMLS ground equipment has been procured, and the C-130 and C-17 fleets have been modified to take advantage of this capability. New C-17s receive multimode receiver avionics on the assembly line and provide FM-protected ILS as well as avionics supporting growth for future differential GPS landing capabilities.

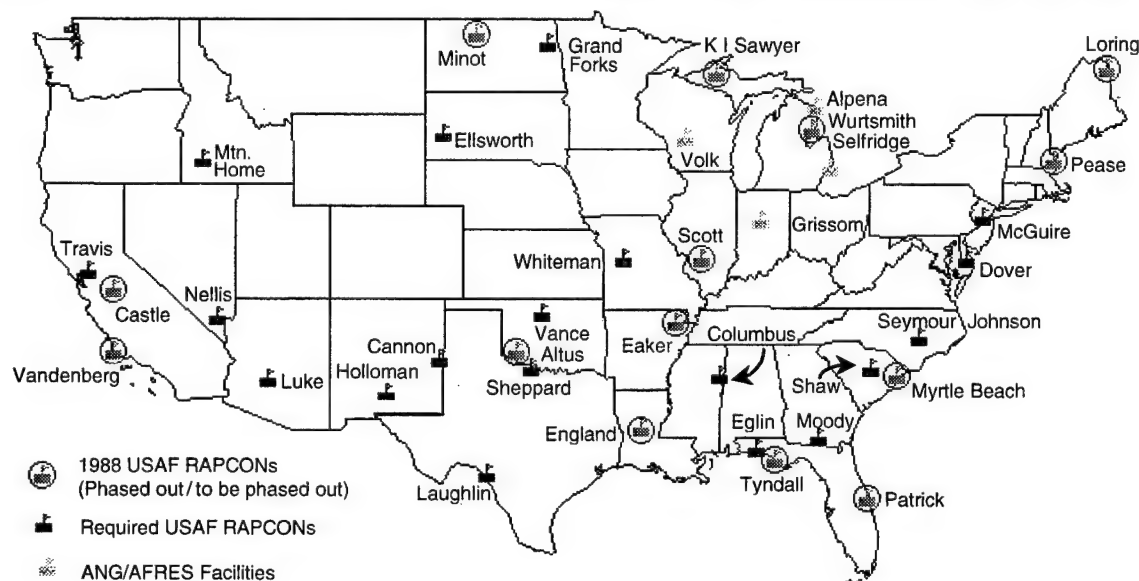
8.3.6 Terminal Control Systems

Terminal control systems include fixed-base RAPCONs and control towers. RAPCONs and control towers include automation systems, surveillance radars, and communications systems.

In 1988, DoD and the FAA signed a Memorandum of Agreement that addressed fixed-base RAPCONs. DoD, with a considerable amount of apprehension at first, agreed to participate in

this joint-Service, Air Force–led program to modernize the fixed-base ATC system in concert with the FAA. This decision was justified by the requirement for DoD to provide ATC-related services to all users, be they military or civilian, in such a manner that the crossing of the boundary of a military or civilian area of jurisdiction would be transparent to the pilot. Additional justification for the joint effort was the operational and cost benefits of system commonality and joint acquisition, training, and logistics support. The DoD decision to join the FAA spawned the NAS Modernization Program.

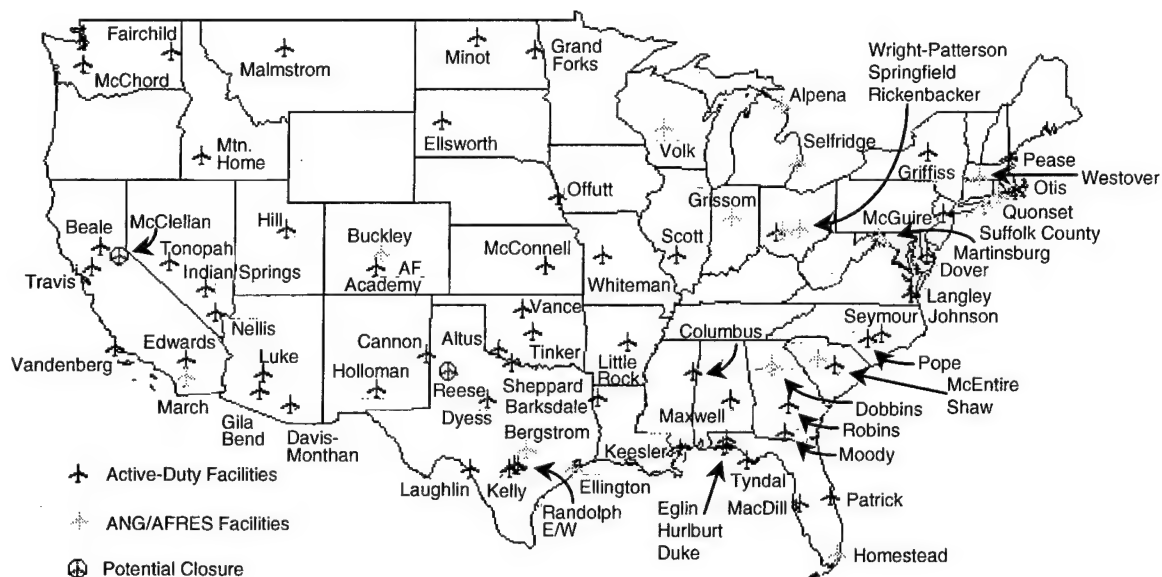
Before defining future equipment requirements, the Air Force conducted an analysis to determine the number of radar controllers needed to support two nearly simultaneous MRCs. After this analysis, the MAJCOMS assessed their requirements to determine the best locations for Air Force RAPCONs. Figure 11 identifies locations where the Air Force will continue to operate RAPCONs as well as locations where the Air Force either has or will terminate RAPCON services.



Note: In addition to the ANG/AFRES facilities depicted, the ANG has commissioned RAPCONs at Cheyenne, WY; Kingsley Field, OR; St. Joseph, MO; and Alexandria, LA.

Figure 11. RAPCON Architecture

As previously stated, the Air Force operates control towers from which air traffic controllers provide instructions to aircrews to provide for the safe, orderly, and expeditious movement of aircraft in the airspace surrounding the base and on the runways and taxiways controlled by the base. Figure 12 shows the CONUS Air Force control tower architecture.



Note: In addition to the ANG/AFRES facilities depicted, the ANG uses FAA contract ATCTs for proficiency training at Cheyenne, WY; Kingsley Field, OR; St. Joseph, MO; Alexandria, LA; Barbers Point, HI; and Key Field, MS.

Figure 12. Control Tower Architecture

8.3.6.1 The DoD NAS Modernization Program

The DoD NAS Modernization Program is an Air Force–Navy–Army initiative to procure new automation/display, surveillance, and communications switching systems with the FAA. This program will ensure that Air Force fixed-base systems will be able to provide the same services and retain the same capabilities as approach controls operated by the FAA.

A COEA conducted in response to Milestone 0 decision guidance found that DoD will experience excessive operations and support costs if DoD NAS equipment is not modernized. The COEA also disclosed that over a 20-year life cycle (1998-2017), procuring, operating, and maintaining new surveillance, automation, and communications switching systems would be \$376 million cheaper than operating and maintaining existing systems. Furthermore, the new systems would provide new capabilities necessary for DoD to provide the same level of ATC service as the FAA.

The program, which received its Milestone II review in April 1995, will address Air Force system deficiencies at 28 radar facilities and 34 ATC towers within CONUS. However, there are no funds to modernize some CONUS RAPCONs, OCONUS RAPCONs, and control towers, or some standalone CONUS control towers.

Without modernization, many CONUS and OCONUS locations will not be capable of providing the services required. Furthermore, procuring and maintaining new equipment will be less expensive than continuing to operate existing automation, surveillance, and communications systems.

8.3.6.2 Surveillance Systems

The Air Force uses ground-based surveillance radars to obtain aircraft position information. Primary radars are independent surveillance systems; they transmit a signal that is reflected from targets such as aircraft. Secondary radars are dependent surveillance systems; they transmit a signal that is received and responded to by an aircraft transponder. By furnishing aircraft information, secondary radar returns enhance the information presented by primary radars.

Current radar systems cannot detect all of the aircraft operating within an airspace sector and do not accurately detect varying levels of adverse weather. They also do not provide radar data in a digital format, which is necessary to interface with future ATM system components. Specific deficiencies include inadequate probability of detection, resolution, reports per scan, and lack of a weather-reporting capability. Furthermore, current secondary radars cannot discern individual aircraft during formation breakup.

With current surveillance system limitations, controllers must frequently restrict flight operations by increasing aircraft-to-aircraft and aircraft-to-weather separation. Increased separation decreases airspace capacity, causing delays that affect mission schedules, available time in training airspace, etc.

Through the DoD NAS Modernization Program, the Air Force will procure new Digital Airport Surveillance Radars (DASR). DASR will provide an integrated primary and secondary radar to improve target detection, provide varying levels of weather-processing capability, and offer a digital output compatible with nondevelopmental item (NDI) automation systems.

At CONUS locations, the DoD NAS Modernization Program will provide the Air Force with ground-based radars that can be economically sustained through at least 2017. A procurement plan exists to acquire all USAF CONUS and all OCONUS radars through FY07. Contract options have been added to accommodate purchase and installation of all radar requirements. The FYDP and the FY00–05 POM fully fund procurement in those years and FY02–07 POM planning is under way to fully fund all options.

8.3.6.3 Automation Systems

The ATC automation systems and analog displays in use today do not have the capacity to process or display all of the flight information from aircraft operating in the airspace delegated to Air Force ATC facilities. Current automation systems also cannot accept radar data from adjacent locations to use when their designated radar goes down. In these situations, procedural separation techniques (which increase separation standards) are used. Furthermore, today's automation systems do not interface with some civil ATC systems. Specific automation system deficiencies include inadequate quantities of flight plans, aircraft tracked, and number of reconfigurable controller displays.

With current automation system limitations, controllers frequently must restrict flight operations by increasing aircraft-to-aircraft separation. Increased separation decreases airspace capacity, causing delays that affect mission schedules, available time in training airspace, time over target, etc.

Through the DoD NAS Modernization Program, the Air Force will procure an advanced automation system beginning in 1998. The DoD Advanced Automation System (DAAS) will consist of NDI computers and workstations capable of displaying the required numbers of aircraft and appropriate flight data. The new system will improve overall system availability.

The DoD NAS Modernization Program currently contains funds to replace CONUS automation systems. Like the DASR procurement under NAS modernization, procuring automation systems for some CONUS and all OCONUS locations requires additional funding.

8.3.6.4 Communications Systems

ATC communications systems include VHF/UHF radios and the OJ-314 voice switching system. VHF and UHF radios are used by air traffic controllers and aircrews during ground-to-air and air-to-ground communications. The OJ-314 is a radio and telephone switching system used by air traffic controllers to change radio frequencies during controller-to-aircrew communications and to change telephone circuits used during ground-to-ground communications.

There are no deficiencies associated with UHF radios; however, VHF communications frequencies have congestion problems. Furthermore, the OJ-314, the system with the most manpower-intensive maintenance in the Air Force ATC inventory, can no longer be economically supported and cannot reassign frequencies in a timely manner.

Reliable communications are required for ATC. An inability or restricted ability to communicate is a safety issue. Communication failures increase accident potential and restrict flight operations by decreasing the number of aircraft allowed in an airspace sector when no-radio procedures are implemented. These restrictions translate into delay. When delays are expected, aircraft must retain additional fuel for approach and landing, which decreases the fuel available for mission-related activity (that is, time over target).

Through the DoD NAS Modernization Program, the Air Force will replace deficient communications switching systems. The Enhanced Terminal Voice Switch (ETVS) will consist of NDI equipment capable of enhanced reassignment of frequencies and will improve system availability.

The current budget provides for the procurement of ETVS systems for CONUS RAPCONs and associated control towers. However, additional funding is needed for some CONUS and all OCONUS facilities to complete the transition.

8.3.7 Navigation and Approach Systems

The 1994 Federal Radionavigation Plan, a joint DoD and DOT publication, prescribes the phase-out of most ground-based NAVAIDs by 2010 in favor of space-based systems. Today's Air Force NAVAIDs provide all of the information necessary to accomplish the navigation service. There are no new investments planned for fixed-base NAVAIDs.

8.3.8 Precision Approach and Landing Systems

The Air Force has three precision approach and landing systems in the inventory: ILS, PAR, and MMLS. These existing systems suffer from a number of shortcomings and limit joint operations. They are moderately difficult to site, do not provide for Service or civil interoperability, do not provide covert, jam-resistant data transmission and reception capability, are highly vulnerable in a hostile or friendly emitter environment, and in some cases are manpower intensive. There are no modifications planned to extend the life of existing Air Force PALS. The future JPALS is expected to provide the DoD's next-generation precision approach capability.

It is imperative for the Air Force to have an effective precision approach capability. Without one, aircraft recovering from training or combat sorties will require greater fuel reserves, which will reduce the time available to accomplish mission objectives. Moreover, aircraft will experience

more landing diversions, which will impair the Air Force's ability to regenerate aircraft for follow-on sorties.

8.3.8.1 Instrument Landing System

The ILS is the Air Force's current primary PALS. Although Air Force aircraft are 100 percent equipped with ILS avionics, the system suffers from a number of shortcomings. It has complex siting requirements (topography limitations), is hampered by frequency congestion (limited number of frequencies available), is plagued by frequency modulation interference problems in some areas (Europe), is not deployable, has limited Service and Allied interoperability (only 30 percent of DoD is equipped), and is planned to be phased out completely by 2010 in accord with the Federal Radionavigation Plan.

8.3.8.2 Precision Approach Radar

PAR systems are used less and less in today's Air Force. In fact, the current trend by the MAJCOMS has been to decommission the PAR in favor of the ILS. PAR systems are manpower intensive, training intensive for operators, airlift intensive for mobile systems, costly to sustain, and difficult to deploy. For example, the mobile PAR associated with the TPN-19 mobile RAPCON requires six C-130s for transport and 26 personnel for setup. Today's PAR systems provide no civil interoperability and are aging, causing significant logistic problems. Although the Army and Navy continue to use PAR and it remains the current NATO PALS standard, the Air Force is phasing out its PARs in favor of ILS since all of its aircraft are suitably equipped.

8.3.8.3 Mobile Microwave Landing System

The MMLS, which is the Air Force's newest PALS, can be used only by Air Force C-130 and C-17 aircraft equipped with suitable MLS avionics. It provides limited civil and allied interoperability.

8.3.9 ATC Training

The Air Force ATC career field consists of approximately 4,000 personnel. Each year, an average of 170 individuals are selected and trained to be air traffic controllers. New controllers receive initial skills training at the 16-week enlisted ATC Technical Course (Tech School) at Keesler AFB, Mississippi, and graduate as Apprentice (3-level) controllers. The "3-Levels" are assigned to operational flying wings, where they receive on-the-job training (OJT). Controllers continue to receive OJT throughout their careers.

The minimum core requirements essential to all levels of the enlisted ATC career field are incorporated into the initial skills course curriculum. However, due to an unclear definition and inconsistent application of these core performance standards, Tech School graduates arrive at their operational units with varying skill levels. Variations in controller comprehension (the ability to apply knowledge) increase the time required for in-unit OJT. This in turn places an additional burden on unit personnel to train controllers. The end result is a decreased ability to support the operational flying mission.

The new-arrival problem is exacerbated by varying levels of aircraft operations and mission complexity at the unit level. Air traffic controllers are "universally assignable." This requires controllers to have a common basic level of knowledge—for example, a controller should be capable of providing ATC service at busy composite wings as well as at locations with a low

volume of traffic. While unit OJT is consistent across the career field, varying levels of mission complexity and aircraft operations throughout the Air Force result in differing controller skill levels.

8.3.9.1 The Air Traffic Control Training Device (ATCTD)

At the Tech School, limited-capability control tower and radar simulators are used to increase controller trainee proficiency without controlling live traffic. Unit OJT is enhanced through the use of the limited-capability radar simulator.

The ATCTD is designed to provide an ATC simulation capability to train apprentice and skilled air traffic controllers in radar procedures. It also has been adapted at some locations for limited-capability computer-based training. The ATCTD was designed to provide a training environment that increases the quantity and quality of training available while reducing the impact of training on operational equipment and personnel. However, its procurement was not centrally managed, which resulted in numerous problems.

The DoD Advanced Automation System being procured under the NAS modernization program includes a radar simulation capability that will remedy the ATCTD deficiencies. However, funding is required for this capability at sites that are not included in the DoD NAS Modernization Program.

A viable simulation capability would reduce the time needed to train during actual aircraft operations, reducing the impact that controller training has on flying operations. It also would reduce controller checkout time at deployed locations by allowing controllers to familiarize themselves with the environment around a deployed location prior to leaving their home base.

8.3.9.2 The ATC Control Tower Simulator System (ATC CTSS)

The ATC Tech School at Keesler operates the only ATC CTSS. This system is used to ensure that tower controllers can learn to separate and sequence aircraft in the vicinity of an airport at a competent level of proficiency before training with live traffic at the operational wing. However, the Keesler simulator uses obsolete technology and requires numerous personnel to operate. The simulator is expensive to maintain, has limited capacity, and does not completely duplicate or simulate real air traffic.

An ATC CTSS is also needed at bases throughout the Air Force to enhance tower controller training. The Pope AFB F-16/C-130 Class A Mishap report of 23 March 1994 identified a serious training deficiency in control tower simulation. All MAJCOMS concur that an ATC CTSS capability is needed to provide controllers with the training necessary to practice controlling aircraft with new and different performance characteristics before they are responsible for live traffic.

A state-of-the-art ATC CTSS would be an effective continuation training tool that would allow controllers to experience demanding situations that may not routinely occur with live traffic. With an ATCT simulation capability, controllers will be better prepared for an unusual situation that may lead to an accident.

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Chapter 9—Future Service Provider Infrastructure

9.1 INTRODUCTION

ICAO has endorsed a new CNS/ATM concept to take advantage of new technology in CNS systems that improve ATM. The “navigation” part of CNS/ATM involves the introduction of satellite-based navigation using a GNSS and introduces the concept of RNP. The “communications” part of CNS/ATM relies on the use of datalink communications to replace elements of voice communications, expands the use of satellite communications to provide both datalink and voice services, and introduces the concept of RCP rather than carriage of specific radio equipment. The “surveillance” part of CNS/ATM introduces the concept of ADS, in which aircraft periodically report their identity, position, and intent. The ADS reports can be either addressed (sent to specific ATC centers) or broadcast (sent to all within line of sight); these two concepts are sometimes known as ADS-A and ADS-B, respectively. Use of ADS-A (usually called simply ADS) requires the availability of a beyond-line-of-sight datalink. CNS/ATM allows for the ultimate definition of RSP and—eventually—for somehow combining RNP, RCP, and RSP into a definition of required total system performance.

Many of the required CNS performance concepts included in CNS/ATM could be achieved through the use of existing or planned military systems. This offers the potential for enabling GANS through the exploitation of existing military capabilities and infrastructure, rather than solely through aircraft avionics upgrades to achieve the assured navigation, communication, and SA enhancements required to be compliant with CNS/ATM performance standards.

9.2 GLOBAL POSITIONING SYSTEM (RNP)

The civilian community is rapidly moving toward space-based navigation to achieve RNP. The Air Force–operated GPS infrastructure is the accepted backbone of this performance. However, while a number of augmentations are being defined to satisfy RNP through GPS signal-in-space enhancements, no efforts have been made to certify avionics augmentations, such as INS, of specific interest to the military user.

Although military users of GPS have access to the PPS, the Air Force has been slow to take advantage of this superior service to implement a GANS solution. Concerns about issues of reliability, integrity, and availability of the GPS satellite signals have been raised, yet the responsibility to provide solutions for these concerns has been left to the civilian community. If this situation remains, the Air Force will be required to refit or upgrade all aircraft GPS navigation equipment to become compatible with GNSS augmentations designed by the civilian community to meet RNP. ICAO has endorsed GNSS as the future global navigation system for primary means of navigation. GNSS is also expected to aid in precision approaches in very low visibility. ICAO SARPs for GNSS to support RNP-1 and RNP-4 requirements are expected to be available as soon as 1998.

The most stringent RNP category currently defined is RNP-1, which requires that the system ensure ± 1 nmi containment for 95 percent of the aircraft’s flight time. A monitor function must be included to alert the pilot when the containment error exceeds 2 nmi. For civilian users, additional geostationary satellite signals, to be provided in the NAS by the U.S. Government, and

globally by Europe and Japan, are required to enhance the current GPS integrity and availability to meet RNP-1.

Military requirements for airdrop, targeting, weapons release, and refueling all call for better accuracies than those specified for RNP-1. If the integrity, availability, and reliability requirements inherent in RNP are also considered, military GPS avionics could be used to meet currently envisioned RNP. This would require the integration of GPS with other avionics equipment, such as the INS, on military aircraft and taking advantage of the improved performance of the PPS provided to military GPS users. This military RNP capability could be achieved without dependence on civil augmentation services.

The JROC has validated the need for a deployable, reliable, survivable, maintainable, jam-resistant, and interoperable precision approach capability. Future systems are being evaluated by the Air Force, Navy, and Army in the JPALS program. The FAA intends to incorporate GNSS-based navigation into the NAS through implementation of the WAAS, an integrity-monitoring and differential GPS. The WAAS is planned to broadcast GPS-like ranging signals modulated with integrity and differential GPS messages to allow GPS to be used to meet performance requirements for all phases of flight down to near CAT I (200-ft DH/0.5-mile visibility) landings.

The FAA expects to issue a notice of public policy on turning off ground NAVAIDs after the WAAS achieves IOC, planned for 1998. FOC is planned for 2001. The FAA expects WAAS to be approved as a primary means for CAT I landing in 1998 and as sole means for CAT I landing in 2001. Local area augmentation will be needed to achieve CAT II and III precision approach capability using GPS. The FAA is now defining the requirements for the LAAS; it expects that the MOPS and a specification will be published around mid-1998.

Assuming that ground NAVAIDs and landing systems are turned off, all NAS airspace users will need to transition to GPS navigation and landing capabilities, including WAAS and eventually LAAS augmentation. The NAS architecture calls for all the FAA's ground NAVAIDs (Omega, loran-C, VOR, NDB, DME, and CAT I ILS) to be decommissioned by 2008 and for CAT II/III ILS to be decommissioned by 2010.

Because civil access to the GPS was degraded (Selective Availability) and because GPS was not designed with an integrity-monitoring capability, the civilian GNSS will likely use a combination of WAAS ranging signals, differential GPS corrections and integrity monitoring to meet RNP. For military users, these same RNP may be realized through improvements in the operation of the existing GPS infrastructure and suitable integration of the PPS GPS users' equipment.

For en route navigation, the RNP can be met by integrating the PPS satellite measurements from the aircraft's GPS user equipment with the aircraft's INS, using receiver autonomous integrity monitoring (RAIM) techniques. With RAIM, redundant measurements from the GPS satellites and other sensors are combined to detect (and identify if possible) out-of-tolerance signals. In essence, each individual GPS satellite measurement becomes a check on the other. The GPS equipment used by the Air Force does not have this capability. Moreover, all of the civil user equipment with RAIM implementation has been developed around the less accurate (SA degraded) SPS.

Dual frequency permits PPS users to achieve P(Y) code observations, high levels of accuracy, and integrity using RAIM techniques. When the GPS observations are validated, they can be applied to calibrate the onboard INS. The calibrated INS will allow continued operation whenever

the GPS signals are not available due to lack of satellite coverage, detected failures, or interference. A GPS/INS solution will be able to support all RNP en route and in terminal areas using the current PPS capability. The combination of the GPS accuracy performance with the continuity of service and reliability provided by an INS results in a powerful integrated solution that adds tremendous capability to each aircraft in flight.

With additional enhancements in the GPS infrastructure, it may be possible to improve the PPS accuracy and integrity so that a GPS/INS solution could also support CAT I precision approach and landing without the need for any ground-based NAVAIDs. The following is a discussion of limitations and possible augmentations to the current GPS infrastructure.

The GPS control segment relies on a network of ground stations to observe and calibrate the satellite errors and three uplink sites to upload corrected data to the satellites. The system response time for the GPS ground segment is significantly slower than for the commercially designed geostationary augmentation systems. Currently, satellite uploads for GPS are performed twice daily and anomalies (or errors) can remain uncorrected for hours. By comparison, the FAA's WAAS broadcast is designed to broadcast integrity alerts within 6 seconds of an error's being detected. Since the WAAS integrity monitors and signal corrections are for the SPS C/A code signal, their utility for PPS users is questionable. It has yet to be proven that failure modes on the C/A code signals always correspond to P(Y) code signal failures and vice versa. It is already known that P(Y) code differential corrections are different than C/A code corrections due to the effect of Selective Availability errors. Additionally, the availability of WAAS signals in theater is questionable since the C/A code WAAS broadcast is not secure and is susceptible to jamming and interference.

The ability of a space-based navigation system to support CAT I precision approach and landing is of significant benefit to the Air Force. A space-based landing system will provide global access to any airfield and will reduce the requirement for forward deployment of NAVAIDs to support CAT I precision approach. Accuracy improvements for GPS have been demonstrated for precision munition guidance (EDGE/WAGE) that have shown performance equivalent to or better than that provided by the FAA's WAAS system. However, neither the EDGE nor WAGE systems includes integrity monitoring or failure notification, which is needed to support precision approach and landing. Further enhancements to the GPS infrastructure are needed to ensure the integrity, availability, reliability, accuracy, and antijam capability before precision approach and landing can be supported by the GPS.

A tightly coupled GPS/INS system using PV-RAIM techniques has the potential to support CAT I precision approach and landing if the accuracy of the GPS signal-in-space is enhanced and the GPS constellation is sustained at 24 or more satellites (with high probability). This accuracy improvement can be achieved through enhancements to the GPS control segment infrastructure. It is already planned to expand the existing base of GPS monitor stations to allow for better modeling and prediction of satellite orbit and clock drifts. Under the WAAS program, JPL has shown that sub-meter orbital location accuracy can be provided for the GPS satellites. The control segment should be able to achieve similar performance (or could even use the WAAS-provided orbits in the interim). The accuracy of the clock prediction is a function of the time between the satellite uploads, since the clocks drift randomly. Currently the satellites are uploaded only twice daily. Hourly corrections are needed to maintain submeter ranging accuracy.

A number of alternatives are available to decrease the latency in satellite clock corrections. The first is to use a geostationary overlay signal to broadcast differential clock corrections to military users. Reliance on the commercial WAAS services being implemented by the FAA and international agencies has serious disadvantages for the warfighters, as the C/A code signals can easily be denied them. As part of the NAVWAR program, serious consideration is being given to the advantages of a military P(Y) code broadband geostationary overlay—P(Y)-WAAS—to augment the GPS satellite coverage and provide antijam protection over theater. The P(Y)-WAAS could be carried as an additional broadband transponder on the same satellite as the civil WAAS transponder. The high-power P(Y)-WAAS signal would also assist in direct P(Y) code search and acquisition by providing the hand-over information needed to acquire the GPS satellite signals. In addition to its NAVWAR functions, the P(Y)-WAAS could also provide real-time PPS differential corrections and integrity data for military GPS users using the commercially developed protocols and standards, but designed to correct for system errors and detect failures on the P(Y) code signals.

Another alternative is to use the WAGE corrections to provide clock correction data. This technique has been demonstrated by the Air Force to support 3-meter accuracy by including range corrections for the satellites in subframe 4 of the satellite almanac broadcast. Since these corrections are provided once only per GPS almanac broadcast (12.5 minutes), they would be vulnerable in a tactical environment where the GPS user equipment may need to operate periodically in the high antijam state-3 mode where data is not demodulated.

The final alternative is to improve the control segment performance itself, instead of relying on differential corrections. The GPS operation can be significantly improved by upgrading the control segment to take advantage of modern communications. By performing frequent navigation data uploads, GPS accuracy can be improved to 1 meter (1-sigma) by providing more frequent clock drift corrections and accurate satellite ephemeris. System integrity can also be improved through frequent updates to satellite health in the navigation data frame (which repeats every 30 seconds). This capability will ultimately be provided by the cross-link capabilities in the Block IIF satellites.

In the near term (until the Block IIF constellation is completed in 2010), the uplink could be performed more frequently through lease or loan of suitable earth station equipment located at allied nations' facilities. The ability to uplink to the satellites in a timely manner anywhere in the world will also significantly enhance the integrity of GPS. Monitoring the GPS signals will be multiple nations and international agencies, including the FAA (WAAS), ESA (EGNOS), and Japan (MT-SAT), as well as a variety of commercial services. Within 6 seconds of an error's being detected, the GNSS integrity geostationary overlays will be broadcasting integrity alerts to aviation users warning them not to use the erroneous GPS satellites. The response time of the GPS control segment could be significantly enhanced if the ground segment were capable of receiving these alerts in a timely fashion (for example, from a modified monitor receiver or directly from the FAA's master control station), and if the control segment were able to react promptly to take corrective action or to disable an unsafe satellite broadcast. Access to additional uplink capabilities could change the response time from hours to minutes, significantly enhancing the safety and performance of the existing GPS constellation.

There is (rightly) much ongoing discussion and concern about the susceptibility of GPS to jamming. The JROC is requiring that the future interoperable precision approach capability be not only deployable, reliable, survivable, and maintainable, but also jam-resistant to support tactical operations. The civilian LAAS GPS CAT II/III landing system under development does

not meet this requirement, as it is designed around C/A code operation, which has no inherent antijam protection. However, the underlying augmentation principle upon which LAAS is structured has direct military utility. The LAAS achieves GPS precision performance through the calibration and dissemination of local-area differential corrections, and augmentation (when needed) by a ground-based pseudolite broadcast. Additional P(Y) code pseudolite broadcasts can enhance GPS performance over a wide area, unlike their civilian LAAS counterparts, which are limited in range due to the poor cross-correlation in the C/A code signals.

The inclusion of a P(Y) code pseudolite into an LAAS solution permits backward compatibility with civilian LAAS installations and will also support DoD's need to provide augmented NAVWAR GPS services in theater. The Air Force, currently responsible for deploying and maintaining navigation aids in the field, should take the leadership role in developing military LAAS—P(Y)-LAAS—to assure GPS navigation services in a tactical environment. Acceptance of a GPS-based solution for JPALS through a P(Y)-LAAS implementation will support CAT II/III precision approach and landing requirements and will be of direct military utility by improving the in-theater antijam performance of all GPS navigation and weapons systems.

9.3 COMMUNICATIONS (RCP)

Air Force aircraft operating under IFR must maintain two-way communications with the appropriate ATC facility or flight service station in accordance with the procedures prescribed for that airspace. If the onboard radio equipment has the capability, the pilot must also monitor emergency frequencies. As ICAO transitions to CNS/ATM, the air-to-ground communication requirements are being defined in terms of the RCP for voice and datalinks. The RCP MASPS being developed by RTCA SC-169 define the RCP for operation within a defined airspace and may also be used to define the RCP for en route and airport terminal operations.

The RCP is characterized using four parameters: delay, integrity, availability, and residual error rates. It is important to note that the RCP MASPS define types of airspace and leave the actual airspace requirements up to the regulatory agency. At this point, the regulatory agencies are unsure of the right approach to handling these MASPS. It is assumed that the existing civil voice communications and datalinks being developed for CNS/ATM will meet these MASPS. However, the goal of RCP is to prescribe the system performance necessary for operation in a specified airspace rather than to mandate carriage of specific avionics.

The Air Force is investing in significant communication infrastructure to provide global C² connectivity. This Global Grid will enable voice and data communications to be transferred in a global network architecture using a seamless combination of commercial, off-the-shelf and military-unique communication services. This connectivity is planned to extend into the cockpit to enhance mission effectiveness and C² connectivity (for example, "sensor-to-shooter").

Commercial Communications Systems Are Required to Achieve Global Robustness

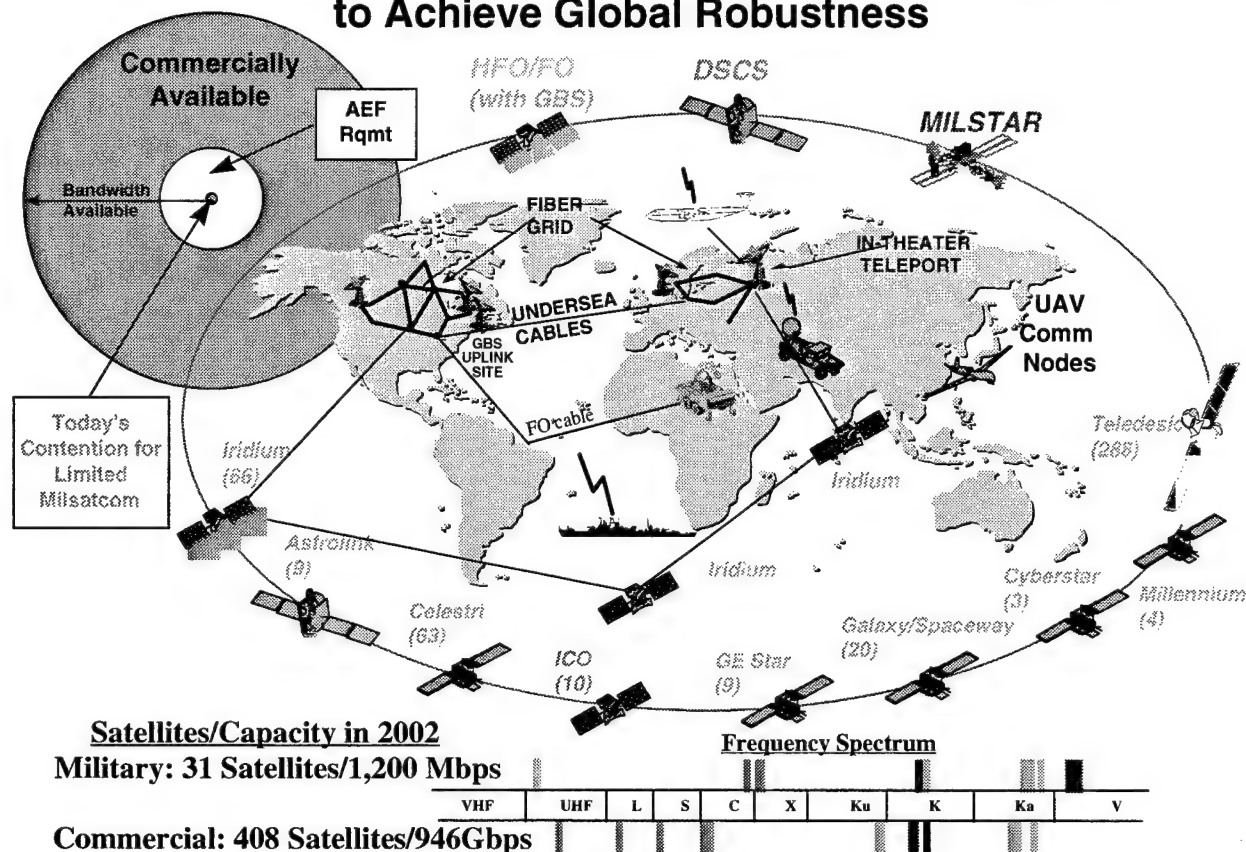


Figure 13. The Global Grid

There is an opportunity to leverage the installed base of aircraft communication systems (such as HF or Inmarsat satcom) to support C² functions and also enable installation of the future Global Grid communication infrastructure (such as satcom or HF DL) to be used to support CNS/ATM functions. Although Inmarsat is the only beyond-line-of-sight communication system currently approved for use as an ATC datalink or for direct pilot-to-controller voice communication, the FAA and airline groups are already investigating the use of planned LEO or medium-earth-orbit (MEO) systems for ATC. Moreover, there is ongoing discussion on the need for direct pilot-controller communications via satellite for oceanic navigation to ensure safety of flight under the proposed reduced separation standards.

Procedures for using satellite voice for direct pilot-controller communications are still being developed. The Air Force, as a large-scale operator of aircraft globally, the provider of an extensive worldwide ATC infrastructure, and an architect of a global C² communications network (the Global Grid), is uniquely positioned to support the development of these procedures. Moreover, the potential benefits to be recognized by the Air Force by establishing these procedures are significant for implementation of GANS. Global ATC connectivity for voice and data through the Global Grid could avoid the necessity of equipping the Air Force's aircraft to be compatible with the wide variety of disparate communications used to support en

route and terminal operations. Instead, the responsibility for enabling the pilot-controller connectivity falls under the management of the Global Grid infrastructure.

For the Global Grid to be used to support the CNS/ATM infrastructure, the communication systems architecture must be designed to be compliant with the RCP for delay, integrity, availability, and residual error rate. A number of technical and operational issues need to be resolved for military communications systems to be used for civil ATC. One issue is capacity. For example, the military UHF satcom system channels are in short supply and great demand. The implementation of demand-assigned multiple access (DAMA) will increase the effective UHF satcom capacity but may increase the communication delay, which will impact the timeliness of ATC communications (unacceptable for meeting RCP). The ICAO SARPs specify satellite system requirements for connectivity, priority and preemption, grade-of-service, allowable routing errors, and call processing and transfer delays. To use a satcom system for safety purposes, communications must be restored within 90 seconds after failure of a primary satellite. Similarly, redundancy or other assurance of rapid failure recovery would have to be provided at the ground stations. To use military systems to support the ATC function, RCP must be considered when these systems are purchased or implemented.

Investment in this ATC network infrastructure will have global impact (and payback) for Air Force operational effectiveness and global access. The Iridium LEO system provider (Motorola) has stated its intention to provide aeronautical service suitable for use as ATS communications. Aeronautical communication data networks are operated in the United States by ARINC (for ACARS) and in most of the rest of the world by SITA via the Aircom system. These systems support FANS data distribution to ATC centers, aeronautical operational control, and airline administrative control. ICAO's planned future infrastructure is the ATN. Expansion of this planned network architecture to support voice and data connectivity into the ATC infrastructure to enable pilot-to-controller communications through a communications network would avoid the necessity of upgrading aircraft avionics to be compliant with all regional communication systems. Moreover, as discussed in the following section, an ATC-compliant communication network (see Figure 14), operated and maintained by the Air Force, will also enable distribution of current ATC support functions among different regional (and mobile) facilities. This will provide the opportunity to implement ATC as a reach-back function, for example, in support of the AEF.

9.4 AIR TRAFFIC CONTROL

To take advantage of the benefits for GANS in adopting (and pioneering) the RNP, RCP and ADS concepts for CNS/ATM, modernization of the Air Force ATC functions is required. The ATC operations of the future are envisioned as an integral part of the Air Force's overall C² structure. The Global Grid connectivity will be able to support pilot-controller connectivity worldwide for both voice and data services. Integration with this global connectivity will enable the Air Force's ATM structure to evolve from a ground-based, analog system into a space-based system.

Whether in combat or stateside, the Air Force furnishes the same ATC services and follows the same ATC procedures as host nations' civil agencies. To provide equivalent service that is transparent to the user, both deployable and fixed-base ATC systems must be interoperable, or capable of exchanging aircraft position and flight plan information with adjacent systems, both foreign and domestic. In the networked ATC architecture illustrated in Figure 14, this interface is used to bridge military voice and data communications and the civilian systems employed in

the host nation. This function minimizes the impact to the Air Force user (in changes needed to equipment, operations, and procedures) while providing full connectivity with civil agencies.

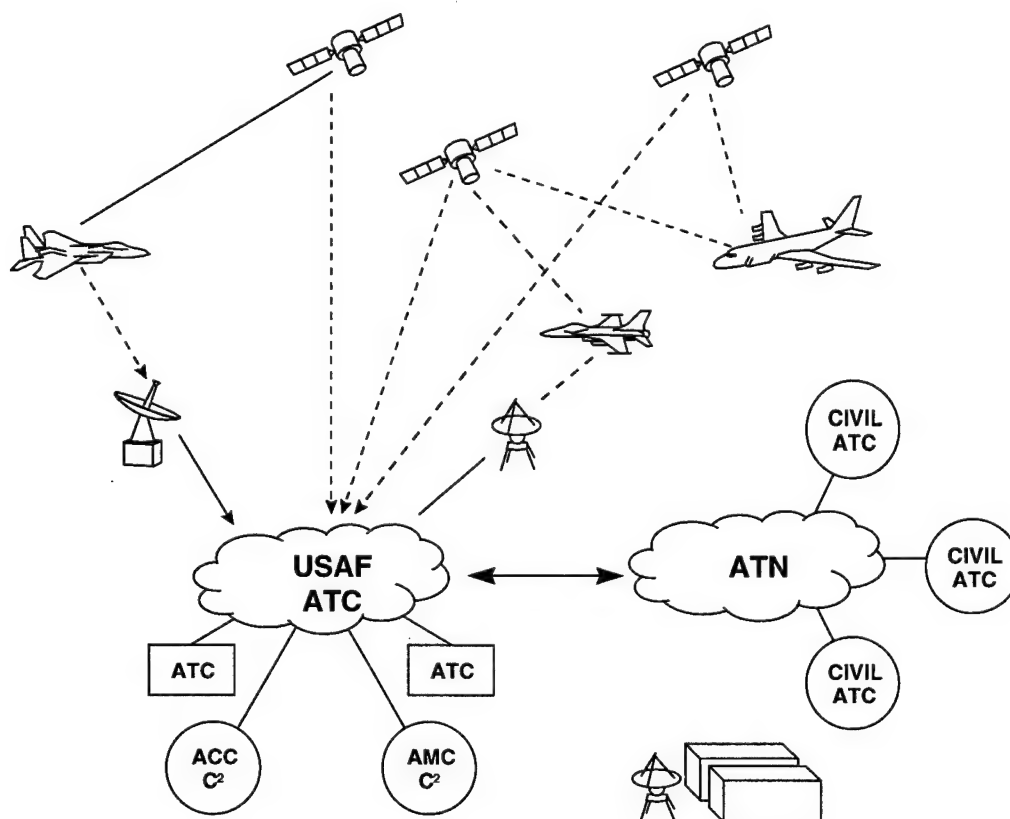


Figure 14. Future ATC Network Concept

The combination of global navigation with global communications allows early implementation by the Air Force of ADS using over-the-horizon communications. This capability would significantly enhance SA in the cockpit and within ACC, AMC, and other Air Force C² commands.

The concept of a networked ATC, as illustrated in Figure 14, with global connectivity through robust, high-speed communication links, enables the vision of operating many ATM functions in a reach-back mode. The current deployable ATCALS are manpower intensive to set up and operate and require extensive airlift to move—deficiencies that have delayed deployment of U.S. forces. The networked ATC allows air traffic controllers to manage and direct traffic in a virtual environment created by linking remote, permanent, staffed facilities with the local-area radar approach control (RAPCON) and ATC towers (ATCTs) used to support combat operations. This capability significantly minimizes the number of personnel and equipment needed to be deployed in the field while still maintaining all of the functionality required for ATM. The benefits in this approach are recognized in terms of the reduced footprint for support personnel, savings in airlift, and reduced risk to ATC personnel.

The virtual environment used to implement reach-back ATC operations also can be used to improve controller training. By replacing the real-time communication links used to connect the ATC network into the field with a simulator function, ATC controllers can be trained in the

same environment used to support day-to-day operations. This state-of-the-art capability would increase controller proficiency levels while supporting the evolution to a next-generation, space-based system.

The reachback capability offers particular advantages in supporting AEFs. As discussed previously, GPS (with enhancements) has the capability to support all en route, terminal area, and CAT I precision approach and landing. This space-based navigation capability, combined with a global communications network and ADS in-transit visibility from all Air Force aircraft, enables ATM to be provided for a limited number of aircraft without the need for *any ground support equipment*. This capability would significantly speed the deployment of an AEF, providing an interim ATM solution until the quantity of air traffic would require deployed ATCTs and RAPCON equipment. The AEF offers an ideal opportunity for early implementation of the reach-back ATC concept to demonstrate the operational benefits of CNS/ATM when embedded in the Air Force's C² structure.

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Chapter 10—International Aspects

10.1 INTRODUCTION

DoD must assume a highly proactive international posture to preserve military global aviation access in the face of significant impending changes in world aviation CNS and ATM programs. To ensure that the impending civil developmental programs that impact the military will account for military needs, a common message must be presented around the globe from the United States with respect to military (state) aircraft operations. The DoD leadership, the FAA, the DOT, and the DoS should communicate a message like this:

In the interest of U.S. national security, and representing the total DoD, the Commander-in-Chief of the Joint Service Transportation Command (CINC TRANSCOM) will ensure that the United States has global access to achieve future military missions.

The approach should be articulated as:

In the present era of decreasing budgets, DoD must become an active participant in the global aviation management process. DoD can no longer afford a reactive role in the development of civil aviation requirements, but must become an active participant to ensure global access for the military operating in civil-controlled aviation environments.

10.2 IMPENDING CHANGES IN INTERNATIONAL GLOBAL MILITARY ACCESS TO AIRSPACE

Ongoing changes in international ATM are intended to increase airspace capacity and improve safety. These changes can also benefit DoD aircraft in carrying out their military mission; however, military adaptation cannot be accomplished without cost. DoD senior leadership must be involved in the international process at the policy level to insure that DoD can be interoperable with new civil system to the extent necessary for optimum mission accomplishment.

Change in the current international aviation environment is driven by sovereign agendas, a diverse user community, and the efforts of several consensus bodies that attempt to coordinate various national positions. These consensus bodies include the 182 nation members of the ICAO, the 33 members of Eurocontrol, some 22 members of the European JAA (a certification body), various ICAO and informal regional groups, and like counterparts in South America, Africa, and Asia. These efforts are not cohesive, and, as a result, international policy and requirements are subject to change over time, are delayed, and get bogged down in involved consensus building. Another result is the proliferation of diverse worldwide and regional solutions, which, while intended as interim solutions, become de facto standards. This has the potential to seriously impact military budgets and access to global airspace.

The FAA was the leader in these international standards development efforts for many years by supplying research and resources for such development. FAA influence is diminishing because of national and regional agendas and because of the FAA's own inability to adapt to rapid technology developments in air traffic automation. This diminishing role and the magnitude of upcoming changes in aviation systems require that the military become active at the highest international levels in cooperation with the FAA and DOT.

The Europeans are implementing 8.33-kHz frequency splitting in the VHF air-ground communications band in opposition to and at great cost to non-European operators flying in and out of Europe. RVSM are being adopted in the Atlantic and soon will be in the Pacific. GPS as a sole means of navigation has been approved for oceanic operations. These and other impending systems changes, both regional and worldwide, threaten ready global access for military operations unless the changes are implemented in a way to which the military can adapt in order to retain access to airspace. So far the military at the policy level has been in a passive, reactive mode, complying with civil aviation standards that have been set by international organizations without specific regard to military needs.

Influencing international consensus in order to ensure retention of military access is complex and needs to be accomplished at the highest levels of U.S. Government agencies, of international civil standards development bodies, of military bodies such as NATO, and within sovereign states. Although the military has been somewhat represented at the working level, there is a void at the policy level in the form of cohesive direction and representation of military high-level policy.

The civil international aviation standards-setting environment is complex and disorderly and does not always reflect the best interest of the United States and its allies in their common military interests.

10.2.1 Approach

The key to this report's recommendations is that the CINC TRANSCOM assume the mantle of leadership in international (and national) ATM to assure global access for the military. This active leadership will assist in the establishment of realistic requirements that can be met within fiscal constraints. The influence that the military can apply in international ATM may provide substantial protection for military operations as well as carry authority to commit to international agreements.

There are three major points that the CINC can ensure are executed:

- DoD needs to be involved actively in decisions as well as in the formulation of requirements
- CINC TRANSCOM must represent the total DoD for military global access ATM in an orchestrated manner (with a strategic plan)
- CINC TRANSCOM commits to equip aircraft in a responsible manner to support all airspace requirements while preserving military global access

10.2.2 International Relationships

As the DoD representative with active participation as the goal, the CINC TRANSCOM should establish and maintain communications with the

- **Administrator of the FAA**—Critical to joint positions around the world and recognition of their vital role in global civilian transportation.
- **Assistant Secretary for Policy for DOT**—Joint policy decisionmaking should be established to ensure global access for the military.
- **Assistant Secretary for Trade for DoS**—Establish the “advertising for American industry in this arena.”
- **Administrator of NASA**—Key discussions on the future of air traffic and global development.

- **Counterpart in NATO (also EUCOM)**—Joint positions for meetings in Europe on military air traffic. Must be consistent with U.S. activities and could leverage the other military members of NATO when required.
- **Director General of Eurocontrol**—Key position in Europe for developing and executing requirements. A must to ensure common development programs to leverage military needs.
- **Director of EG-7**—DOT for the EU is a key relationship for European requirements.

10.2.3 Necessary Steps

To execute this program, some key steps must be executed that would enable the role to be developed and initiated:

- A strategic plan should be developed (with CINC TRANSCOM as the recipient) that establishes a path to follow and messages to carry, with tri-Service agreement to both the strategic plan and to the role of CINC TRANSCOM.
- Agreement within DoD and the FAA that the CINC TRANSCOM speaks for the military with respect to global access requirements and programs necessary to execute the missions of the future.
- Discussions must be established at the proper level throughout the world to ensure that DoD is actively involved in developing the requirements sets necessary to execute its missions.

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Chapter 11—Liability

11.1 LIABILITY FOR LOSS

An issue that may not have been adequately addressed by DoD in the provision of global positioning and time information via satellite (GPS) is the liability associated with the potential loss of life (worst case), property, or money if the information being provided by DoD's system is held responsible for or contributory to the loss. Because the system has been formally offered by the U.S. Government to the ICAO as the backbone for GNSS, some level of liability is almost certain. Given that the system has been offered globally to a potentially very large and highly diverse user community, that liability may be orders of magnitude greater than similar previous exposures (for Omega or Loran, for example). The issue therefore is whether liability exists, and the level of exposure of the U.S. Government.

11.2 BACKGROUND

Addressing aviation specifically, each sovereign nation's CAA (the FAA in the United States, or the CAAC in China, for example) is wholly responsible for its sovereign airspace and for the control and management of all air operations within that airspace. With that responsibility comes a certain liability (varying by country) associated with the provision of ATC and ATM services, including selection of NAVAIDs approved for use by those operating in that airspace. This has become a contentious issue with several CAAs around the world regarding the adoption of GPS (or any other single-source navigation solution) as more than a supplemental means of navigation within the airspace for which they are responsible, as they would be accepting responsibility, and therefore liability, for a navigation system that is not under their control. (Consider, for example, that the Russian Federation's system, GLONASS, was completely turned off without prior warning [and therefore presumably unintentionally] on 1 July 1997 for nearly 24 hours.) The extent to which intergovernmental responsibility lessens the specific liability of DoD has not been tested in the courts. It should also be noted that there is a serious international effort under way to establish a new (and more onerous) liability regime specifically focused on the introduction of GPS-like systems.

Numerous proposed GPS augmentations not only attempt improvements to the basic system being provided to the civil user (improving accuracy, integrity, availability, etc.), but also give the CAAs some participation, and therefore authority and control, over how the system is used within their sovereign airspace. Whether these augmentation systems will be perceived over time as sufficient to defuse the single-provider concerns of these and of nations having no such augmentations or control is uncertain. Likewise, in application of the Federal Tort Claims Act and the Suits in Admiralty Act, where negligence (the absence of reasonable and diligent efforts) must be proven to effect liability, the integrity provider may be at the greatest risk.

11.3 EXPOSURE

To date, there has not been an accident or incident in which GPS has been implicated as a cause or contributor. However, as greater dependence is placed on the system, and its precision capability is exploited to the point where it is widely used in conditions of very low visibility

(such as CAT II/III landings), GPS is inevitably going to be linked to an accident or incident and claimed to be to some extent liable, even if only to ensure that, upon successful litigation, someone with deep pockets is available to pay. The FAA has considerable experience in this area, and has for this reason (despite user community accusations of obstructionism) remained extremely conservative in its approach to certification of both man and machine—pilots, controllers, maintenance personnel, aircraft, and ATC/ATM equipment.

Resolution of the liability issue is imperative if GPS is to be accepted by the world service provider community. While user pressure will continue to push for worldwide implementation, concerns over lack of local control (and trust), especially in today's litigious society, may thwart full acceptance and therefore full implementation. Whether the current movement toward RNP, in which it becomes incumbent upon the user to certify compliance rather than technology, will alleviate some or all of the liability concern is unknown.

11.4 LIABILITY FOR CONTINUATION OF SERVICE

An attendant issue associated with GPS is whether DoD is in a position of liability for continuation of service. By deploying a system that has been formally offered for use to the world community, has DoD placed itself in a position of responsibility for the continuance of GPS and, as a result, direct or consequential liability for failing to keep the system fully operational or at some point choosing to discontinue the provision of service altogether? The likely answer is yes, with the true implications of such future liability unknown. While commitments already made to the world community push any decision on this issue out several years, it will at some point have to be considered. The provision in the commitment made to the world community for 6-year notification of change or discontinuance, while providing a possible out for DoD, may not remove that liability from the U.S. Government.

11.5 RECOMMENDATION

This board does not have a full grasp of all of the implications of liability for DoD with regard to the provision of GPS services, understanding that several of them are being addressed. We would therefore recommend that this subject be thoroughly investigated and that a clear position for going forward be established. Of immediate need is an official statement describing exactly what DoD is providing and what it will continue to provide, with all the limitations of the system and the system provider clearly stated.

Chapter 12—Demonstrations

12.1 INTRODUCTION

The major cost identified in implementing GANS requirements is the modification and integration of new avionics into DoD aircraft. These cost estimates are driven by integration and extrapolation in other equipment programs, and in equipment integrated for capability demonstrations performed with prototypical or experimental equipment as the precursor to operational equipment. A possible new program for the deployment of GANS equipment at a reduced cost could be through a modification demonstration program. The resultant modified aircraft could then be used in verification of the equipment capability. A developmental demonstration is primarily driven by performance issues. The focus of this program would be to determine means of simplifying equipment to be integrated, introduction of easily modifiable equipment, or the use of add-on (possibly expendable) equipment for mission deployment.

To provide the focus and establish a solid foundation for costing, the modification demonstration could be established as an advanced technology demonstration (ATD). To validate new and more efficient methods for aircraft modification or upgrading, the demonstration should be performed across representative aircraft classes and missions, selected to sample all the affected systems. With these aircraft, different methodologies indicated by the mission and similarity to commercial aircraft could be determined and evaluated to validate cost-effectiveness.

The methodologies to be evaluated could range from specialized aircraft pods that could be quickly hung from tactical fighter pylons and plug into the avionics system through existing interfaces, to a completely new model based on commercial airline practices. New technology equipment could be investigated, such as digital receivers configured to be controlled primarily through software. This type of software-controlled equipment could be reconfigured by reloading the software, and, in principle, the aircraft could be configured by downloading software through a standard interface during routine maintenance.

The high costs involved in integrating aircraft equipment is in large part due to the process of modifications to the operational aircraft, beginning by platform program after the individual system equipment validation in the development phase. An integrated operational design requires tailoring the interfaces into the particular airframe, and tailoring electronic interfaces to the other equipment on the aircraft. The specific design of the integrated equipment then is dependent upon the specific airplane to be modified. Within the same class of aircraft there could be several variations in the equipment suite and associated antenna systems. The specific modification would then be different for the particular aircraft. Equipment developed under different systems programs is typically designed to provide a specific capability and possibly different capability in different user scenarios.

The GPS equipment development is a good example of a general-purpose system with equipment that provides a range of capabilities. GPS equipment is highly dependent on the implementation in the receiver—not all receivers being equal. Tailoring the equipment to the avionics suite then becomes more complex and dependent on the specific capability desired in the aircraft. In some cases, embedded GPS receivers in different subsystems have been considered to provide different outputs—for example, position in one case, and time in another.

Configuration information and documentation control are critical to maintaining effective integration, and is a large cost factor. The integration would first involve the mechanical modification to install antennas, cables, and associated hardware to actually mount the equipment. To interface the equipment could require additional electronics to provide electrical interfaces and software to enable the specific equipment to communicate with the other equipment in the aircraft. After and during the integration of systems, testing would be involved to ensure that the aerodynamics of the aircraft were unchanged or within specific limits, and electronically to verify emission controls, compatibility, and functionality. If the configurations of the aircraft to be modified were similar enough to use a common integration design, then the actual modification process would be less expensive to implement.

12.2 COHERENCE IN DEMOS

In the various programs relating to GANS and advanced avionics, different aircraft program offices and groups are pursuing aircraft programs with different objectives and goals. These programs may be operating at cross purposes rather than toward an integrated common goal. An ATD program with the objective of reducing implementation costs could be established quickly and of sufficient duration to provide a focus for the various programs. An effective demonstration made up of a program team or IPT from the different centers involved in aircraft integration could address fighter, airlift, and rotary-wing aircraft types and missions. To be most effective, it should be a joint-Service team made up from all DoD Service agencies involved in integration, since GANS requirements cross Service boundaries. Joint objectives and an approach to various aircraft integration demos could be established to validate cost-effectiveness for DoD as a whole. The different elements of GANS and various resources could then be focused on a joint DoD solution.

These large cost estimates and the clear benefit associated with direct reduction of integration costs provide a major opportunity for the demo team to perform lean aircraft demonstrations, requiring a commitment at the highest level to two meta-principles, which describe a lean enterprise: it is responsive to change, and it actively works to minimize waste. Waste minimization is the basis of affordability, while a changing environment is one of the constants describing the situation today. Waste in the case of cross-DoD agencies may mean possible duplication of efforts and resources' being employed in the integration and maintenance of the DoD fleet of aircraft.

Adherence to these two meta-principles principles may substantially reduce integration costs for the Air Force and DoD. Lean demonstrations will indicate that the Air Force is committed to lean and new ways of doing business as well as to implementing the GANS requirements.

Chapter 13—Future ATC Infrastructure

13.1 INTRODUCTION

The future ATC environment in which the Air Force must operate is experiencing the greatest change since surveillance radar for ATC was first introduced in the 1950s. The worldwide ATM structure is evolving in a big way, much of it due to significant advances in communications, digital technology, and GPS.

The development and deployment of GPS by DoD for en route navigation and precise weapon system delivery—without dependence on ground-based systems—was a technical development of immense proportions. The subsequent decision by President Reagan to provide a version of the GPS signal to civil aviation worldwide initiated a series of events that has forever changed the ability of Air Force decisionmakers to acquire ATC systems independent of decisions made by organizations outside the Air Force's sphere of influence.

Nevertheless, the possibilities for GPS application in ATC are huge: nonprecision approaches, precision approaches, distance information, approach and departure routings, sequencing and separation of aircraft, reduced spacing of aircraft, and safety enhancements. With GPS, an entire infrastructure of existing ATC ground-based systems could be eliminated. This is precisely where the Air Force and DoD will have no choice but to go. At present, the vast network of ground systems is manpower intensive, technologically obsolete, and expensive to operate and maintain. Like its civilian counterparts in the FAA, the Air Force needs to be moving toward a seamless, less restrictive, less ground-dependent airspace environment.

While GPS offers tremendous capabilities in transportation management, DoD must be careful about placing too much dependence too soon on a system with vulnerability to intentional or unintentional interruption—a vulnerability that has not been fully recognized or overcome. Therefore, Air Force transition to the ATM environment must follow a careful strategy, perhaps combining the old (as a backup) with the new. Once GPS's capabilities are fully exploited and controlled, the Air Force should remove as much of the ground infrastructure as possible. In the interim, the Air Force should forge ahead with a complete modernization of its ATC infrastructure with the "hooks in place" to allow full incorporation of GPS technology and capabilities.

13.2 THE FUTURE DOMESTIC ATM ENVIRONMENT

Using satellite-based and communications networking technologies, the future domestic and oceanic ATM systems will be seamless—that is, they will employ similar systems and procedures regardless of location. However, complete transition to the new environment may not be completed in the near term. Therefore, the near-term domestic CNS concept must maintain some reliance on current ground ATC capabilities, albeit upgraded, particularly in terminal areas. Terminal air traffic controllers will continue to separate and sequence aircraft. Pilot-controller connectivity will include both voice and data. Radar will continue to provide some aircraft position information but the introduction of Mode S secondary radars will facilitate the selective interrogation of aircraft. In addition, ADS-B will be introduced in the en route structure where aircraft broadcast position information derived from GPS and corrected by WAAS to the ATM system. WAAS

corrections will be transmitted from ground earth stations through communications satellites. GPS and WAAS/LAAS) may also provide precision approach information in the future for DoD aircraft, eliminating the need for ILSs and PAR. Datalink networks will route CNS data. Figure 15 depicts the future domestic ATM environment.

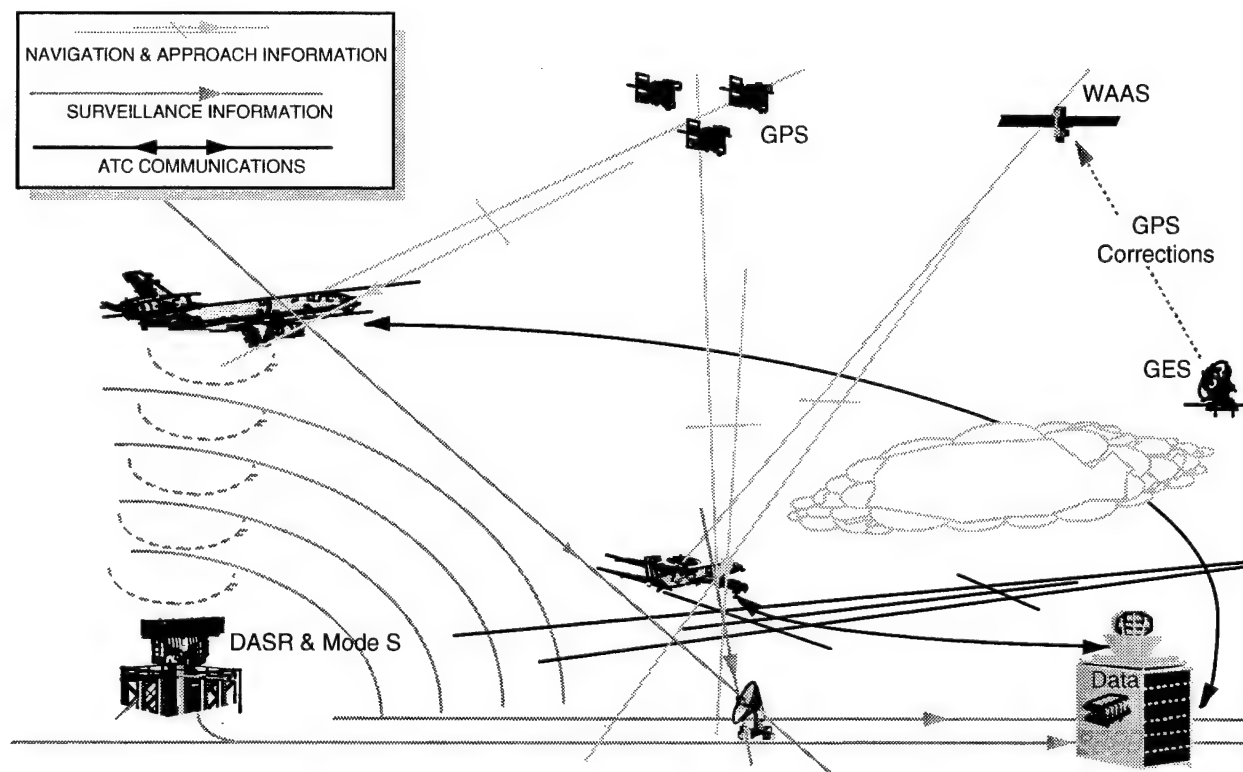


Figure 15. Future Domestic ATM Environment

13.3 THE FUTURE OCEANIC ATM ENVIRONMENT

In the foreseeable future, the greatest changes will occur in the oceanic environment. Here we expect the full implementation of satellite-based CNS. Aircraft will relay GPS/WAAS-derived positions to the ATM system through communications satellites. The same satellites will be used to relay aircrew requests and ATC instructions, many of which will involve ATM computer-to-aircraft computer datalink. The datalink network will route the CNS information accordingly. In the oceanic environment we expect the first implementation of aircrew-based separation. Today, some airlines are already using a TCAS "in-trail climb" procedure in which aircrews coordinate maneuvers that allow aircraft to pass one another. Figure 16 depicts the future oceanic ATM environment.

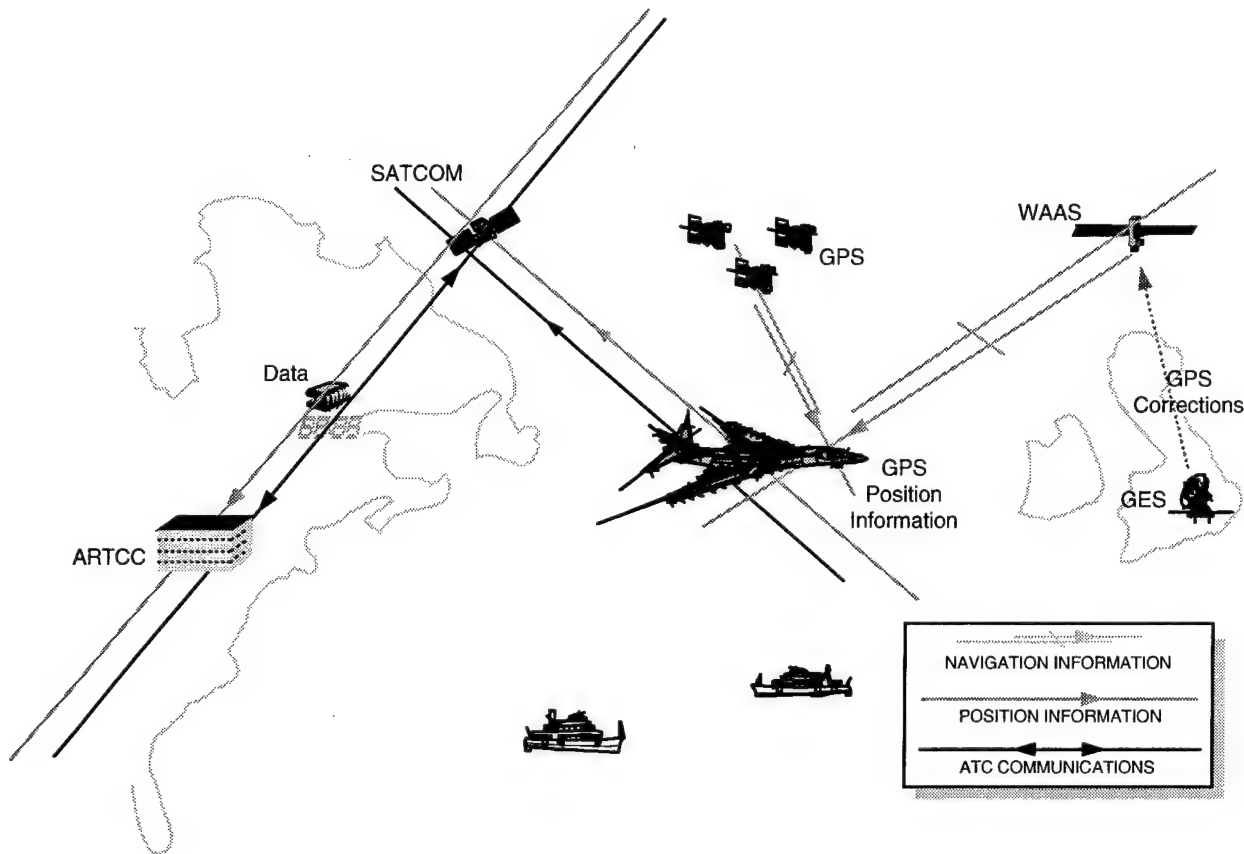


Figure 16. Future Oceanic ATM Environment

13.4 FUTURE MILITARY NEEDS

In the future, the requirement for ATC support will still exist. A capability must be available to provide the sequencing, separation, and traffic information that controllers provide today. In addition, the need to maintain vigilance over the airfield—a task now done by tower controllers—will not go away. As long as there are military requirements to deploy air traffic controllers overseas to support contingencies and/or combat operations and to provide ATC support to host nation allies, the Air Force must continue to maintain a CONUS-based ATC infrastructure fully interoperable with the FAA as well as a readily available capability to provide ATC services overseas.

13.4.1 Deployable Systems

The current TPN-19 and MPN-14K mobile RAPCONs are not adequate to support today's requirements, let alone future wartime requirements. Due to their age and dated technology, the deployable ATC equipment suites will soon be unable to support Global Reach and TBM force employment strategies. Their deficiencies have been documented in the previous section. Though modifications have been validated (though not funded) to upgrade these systems, it should be noted that none of the approved TPN-19 or MPN-14K modifications will allow currently deployable RAPCONs to exchange flight data with future ATC and/or TBM systems. Figure depicts a future scenario showing the required interfaces for deployable RAPCONs. It

also shows how satellite-based systems will be used to provide aircraft with navigation and approach information.

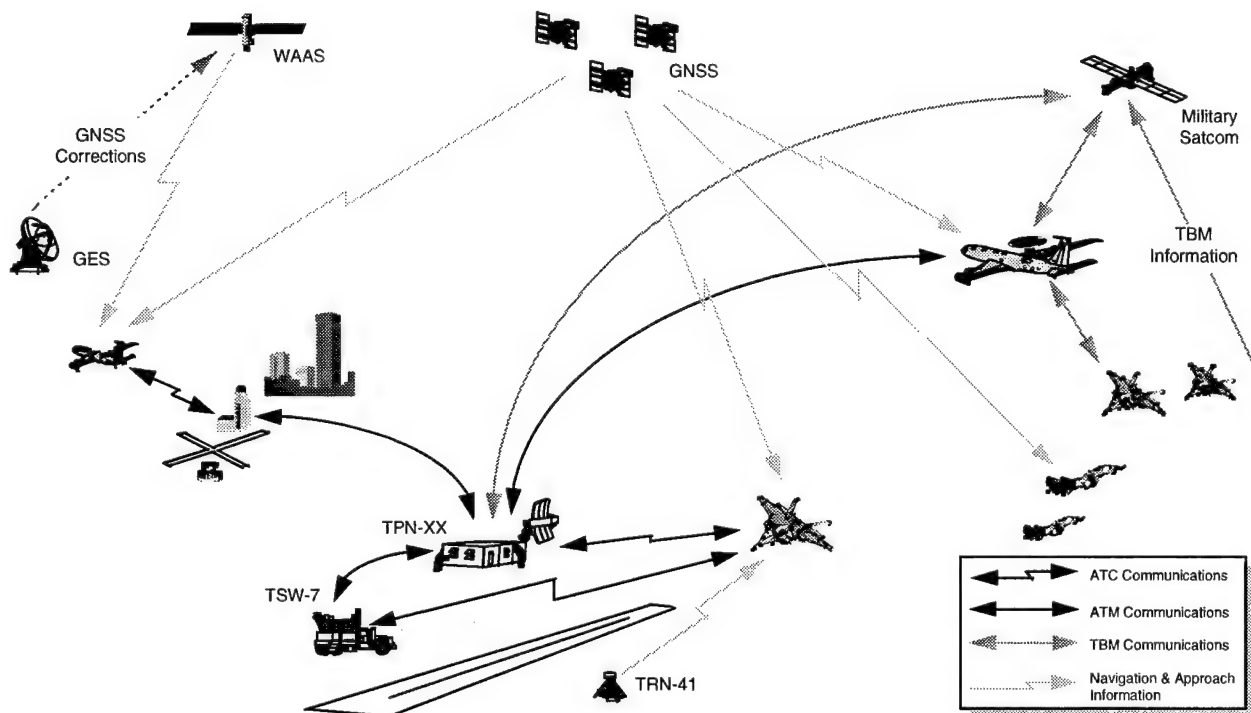


Figure 17. *Deployable ATCALS Interfaces*

The best solution to meet the Air Force's current mobile RAPCON needs is to procure a new state-of-the-art system logistically compatible with the NAS Modernization Program systems. This would provide the greatest degree of commonality and functionality for the Air Force.

Without modern deployable RAPCONs, the Air Force will not be able to effectively support combat forces in the future ATM environment. Current systems will not interface with adjacent ATC and/or TBM systems. Lack of interface will increase nonautomated communications requirements with a proportionate increase in departure and arrival delays. Delays getting to and from the target result in less fuel available to accomplish mission objectives and reduced sortie rates.

The Air Force should also pursue an "out-of-the-box" approach to meet its ATC overseas mission. Using the technological advances of worldwide communications connectivity and GPS, approach control activities could be conducted at geographically distant locations from the contingency or combat environment. In fact, ATC operations could possibly be provided, at least in the initial deployment, from anywhere on the globe, provided a sufficient reachback capability existed. Using the ADS concept and the Global Grid communications network, the environment in which the aircraft is operating would be completely transparent to the air traffic controller. This is similar to the ATC Centralized Facility concept, which failed miserably within the FAA. Infrastructure enhancements to support this must include pilot-controller connectivity, both

voice and data; reachback capability involving real-time transmission of aircraft position for identification and, if necessary, sequencing and separation; weather and airfield status information; unaided GPS for precision approach and landing, if possible; and accurate survey data.

Note: Aircraft spacing, without sufficient reach-back, could use GPS for positioning, velocity, and time. For a mission in an austere environment—under the AEF scenario, for example—this reach-back capability offers the greatest potential. Not only are the logistics footprint and tail reduced or eliminated in the field, but the exposure of ATC personnel to physical threats is mitigated. Thus, in an AEF scenario, no ATC equipment may need to be deployed to an austere location except for a small combat control team to maintain airfield vigilance and security. It's also possible that some form of reach-back capability could be employed for longer-term deployments, perhaps in support of rear bases. However, in a prolonged scenario, some form of "man-in-the-loop" is needed to perform the on-scene control tower functions that extend beyond ATC.

13.4.2 Terminal Control Systems

It is not envisioned that the functionality of the terminal approach control area will change any time in the foreseeable future. While en route radars may be phased out in the next 10 to 15 years, radars will most likely continue to provide surveillance capability in the terminal area. The DoD NAS Modernization Program outlined in the previous section provides for future GANS capabilities through preplanned product improvements (P³Is). There is, for example, an automation system P³I that provides for processing aircraft-furnished position information, a key aspect of the future ATM environment. To achieve this, however, funding is needed for this and other capabilities that may be required in host nations before they are needed in the United States.

Without ATCALS enhancement to operate in the future ATM environment, the Air Force will not be able to meet its obligation to provide the same level of ATC service as the FAA or host nation. Furthermore, Air Force aircraft will experience delays leaving and entering Air Force-controlled airspace. Also, Air Force aircraft upgraded with the newest avionics may not be compatible with ground systems.

13.4.2.1 Surveillance

The future surveillance concept is seen to move from the traditional use of ground-based radars to the use of ADS systems that transmit GPS-derived aircraft position information to the ATM system. The improved position determination capability available with ADS will eventually permit reduced-separation standards. This will increase system capacity by allowing more aircraft to occupy airspace sectors. ADS is already being used in some oceanic airspace where there is no radar coverage. ADS should eventually lead to the selective decommissioning of en route radars. However, there are no known dates for full ADS implementation in CONUS airspace. Consequently, ground-based radars will remain in use well into the next century.

Through the DoD NAS Modernization Program, the Air Force DASR procurement provides for a P³I that will permit the upgrade to a Mode S capability so that the system can discern more targets in a confined area. At CONUS locations, the DoD NAS Modernization Program will provide the Air Force with ground-based radars that can be economically sustained through at least 2017. However, procurement of radars for some CONUS and all OCONUS locations, as well as any P³I, requires additional funding and should be pursued.

13.4.2.2 Automation Systems

As stated earlier, the ATM surveillance concept will migrate from a system that is radar-based to one that uses aircraft position reporting either relayed through communications satellites or broadcast directly to ATC facilities. This ADS concept dictates that future ground automation systems be capable of processing ADS surveillance data. However, ground-based radar will exist well into the next century. Consequently, the future automation systems will also require a capability to process ground-based and ADS surveillance information. The initial versions of the DAAS will not be capable of processing aircraft-generated position reports. As the ATM system transitions into an ADS environment, automation systems must be capable of processing position reports received from ground-based radars as well as aircraft-generated reports. Therefore, future automation systems must be capable of processing both types of surveillance information, a capability addressed as a DAAS P³I. The DoD NAS Modernization Program contains funds to replace automation systems at CONUS locations. Like the DASR procurement under NAS modernization, the automation P³I requires additional funding.

13.4.2.3 Communications Systems

In the future ATC environment, there will be an increased use of datalinks to exchange information. Datalinks will be used to relay traditional controller instructions to aircraft as well as aircraft position information to ground automation systems. Communications vehicles could include VHF and Mode S frequencies. The future communications switching system must be capable of routing data communications. Through the DoD NAS Modernization Program, an ETVS P³I will provide for an ADS routing capability through a datalink router. The Air Force should support this initiative.

13.4.3 Navigation and Approach Systems

In the future, navigation services will be provided by the GPS in lieu of ground-based NAVAIDs. GPS technology will enhance an aircraft's ability to fly optimum routes by removing the restrictions associated with fixed navigation points defined by today's NAVAIDs. This use of GPS will also provide for flexible departure and arrival routes, thus removing restrictions associated with standard instrument departures and standard arrival routes. To fully implement the use of space-based technology for navigation, the FAA plans to employ WAASs that will increase the accuracy of commercially available GPS signals. In the interim, the Air Force must continue to support existing ground-based TACANs until GPS user equipment suitable for primary navigation is installed on all Air Force aircraft.

13.4.4 Precision Approach and Landing Systems

The U.S. DPG describes the need for U.S. military forces to be highly mobile and capable of "rapid response" to a wide range of military options globally. A precision approach and landing capability is absolutely critical to this objective. Capabilities supporting aircraft operations and recoveries, such as precision landings systems, are driven by Mission Areas 260, Mobility; 340, Theater and Tactical Programs; and 356, Mobility. A next-generation capability is needed to replace existing precision landing systems such as the ILS and PAR to eliminate the deficiencies brought by these systems and to enhance joint warfighting capability. The future PALS must be manpower conservative, affordable, supportable in the field and aboard ship, rapidly deployable, capable of operating in adverse terrain as well as conditions of adverse

weather, able to operate within the parameters of the defined threat spectrum, and interoperate to the highest degree consistent with mission needs. The next-generation PALS must allow participating units to land on any suitable surface worldwide (land or sea) while minimizing ceiling and visibility as limiting factors.

The need to address PALS was first highlighted in April 1992 when the Assistant Secretary of Defense for Command, Control, Communications, and Intelligence directed a study to analyze existing and emerging precision landing systems and to develop a road map for the future. This was initially based on the issue that DoD currently relies on a mix of aging land- and ship-based landing systems, which are deficient in the areas of interoperability and tactical mission support. It was also recognized that worldwide support for the MLS (which was going to be the international PALS standard) was waning and that GPS offered a promising capability for precision approach. The C³I tasking was passed through SAF/AQ to the DoD Policy Board on Federal Aviation, which chartered the Precision Landing Study Advisory Group (PLSAG). Developed by the Air Force and Navy, the Precision Approach and Landing Capability (PALC) Mission Need Statement (MNS) was a product of the PLSAG.

The PALC MNS was approved by the Chief of Naval Operations on 28 July 1994 and by the Chief of Staff of the Air Force on 8 August 1994. It was validated by the JROC on 29 August 1995. At the time of MNS coordination, only the Air Force and Navy were joint partners; the Army was designated joint interest. However, just before the Defense Acquisition Board Readiness Meeting in May 1996, the Army joined the program as a full joint partner. On 28 May 1996, the Principle Deputy Under Secretary of Defense (Acquisition and Technology) issued a Milestone 0 (Concept Exploration Phase) Acquisition Decision Memorandum (ADM) for JPALS. The ADM established the following exit criteria for a Milestone I Defense Acquisition Board:

- Conduct an AoA of the potential materiel alternatives
- Recommend the most promising alternative(s)
- Provide acquisition strategy for the next program phase.

The Air Force was designated the lead service for JPALS.

The Air Force is lead time away from fielding a new system. It is estimated that 10 to 15 years are required to develop, acquire, and install new avionics on the Air Force fleet of approximately 6,500 aircraft. Any future PALS will affect both ground- and air-based system platforms. Providing precision approach accuracy, reliability, and integrity will be the major cost driver.

Like the evolution of navigation systems, it is envisioned that future precision approach instructions will be greatly supported by GPS. However, as DoD operates in hostile and austere environments requiring rapid and efficient system deployment, the civil GPS-based solution for the future may not meet all DoD requirements. The future DoD precision landing system architecture under JPALS should therefore consider other existing and new technologies, as well as more robust applications of GPS technology other than the civil standards (unaided GPS, for example).

To provide a viable precision approach capability, the Air Force must:

- Sustain existing precision approach systems until a replacement system is in place
- Complete the JPALS AoA
- Budget for the replacement system
- Capture any GPS-related PALS requirements in other GPS and GPS-user equipment efforts

It is imperative for the Air Force to have an effective precision approach capability. Without one, aircraft recovering from training or combat sorties will require greater fuel reserves, which will reduce the time available to accomplish mission objectives. Moreover, aircraft will experience more landing diversions, which will impair the Air Force's ability to regenerate aircraft for follow-on sorties.

13.5 ATC TRAINING

The key to the successful execution of any Air Force mission is training. To be effective, the training must be dynamic, it must be challenging, it must be realistic, and it must be cost-effective. ATC, particularly in the control towers, must rely on live traffic for its training needs. The use of static models is fine for demonstration and classroom instruction; however, it simply does not meet the needs of the Air Force—namely, aircraft operators. While it is important to stress expeditious handling of traffic, safety cannot be overlooked. The Air Force should not rely on live traffic to fill the lion's share of its ATC training needs, which is what it's doing now. This is not cost-effective, either for the ATC operator or for the pilot, who in all likelihood is training too. This has the potential to creating unsafe conditions plus the loss of valuable time, which translates into dollars.

The future of ATC training must capitalize on the superior benefits offered by automation and technology. This is reinforced by an Air Force Chief of Staff message dated 27 January 1995 which states, in part, "I am convinced that expanded involvement and investment in advanced simulation technologies will improve readiness and reduce costs for the nation because it will allow us to demonstrate the flexibility, responsibilities, and utility of air power in peace and war. We should view this as an opportunity rather than a threat to our live training and exercise hours." Fortunately for ATC, there is light at the end of the tunnel; more, however, is needed to complete the training requirements.

13.5.1 Terminal Approach Control Training

Beginning as early as 1999, new controller workstations and voice switching systems will be fielded through the DoD NAS Modernization Program. This will provide the dynamic realism needed in the radar facilities. Again, the problem faced by the Air Force goes back to the basic NAS program architecture: not all Air Force locations are funded. The Air Force needs to fund the remaining locations prior to expiration of the existing NAS contracts.

The viable simulation capability provided in the DAAS will reduce the time needed to train during actual aircraft operations; this would reduce the impact that controller training has on flying operations. It also would reduce controller checkout time at deployed locations by allowing controllers to familiarize themselves with the environment around a deployed location prior to leaving their home base.

13.5.2 ATC Control Tower Simulator System

During the FY98 POM exercise, the Air Force provided \$28 million in FY03 for a unit-level ATC CTSS. Currently, there are no funds allocated for these systems in any year other than FY03. This is not enough, however, to complete the entire Air Force program. An additional \$36 million is needed. Given that the future demands of training lie in simulation, the Air Force should consider expediting the ATC transition to simulation (since safety of flight could be impacted) and fully funding the effort.

A state-of-the-art ATC CTSS would be an effective continuation training tool that would allow controllers to experience demanding situations that may not routinely occur with live traffic. With an ATCT simulation capability, controllers can prepare for a deployment prior to actually deploying by experiencing a simulation of the airfield operating environment.

13.6 SUMMARY

The Air Force operates ATCALS to support JCS/Air Force-directed contingency and wartime operations. Whenever tasked, the Air Force must be ready to project ATC capability to enhance the effectiveness of combat operations. To maintain an effective combat support capability, the Air Force absolutely requires modern, state-of-the-art ATCALS and a trained cadre of personnel to operate and maintain this equipment.

To ensure that trained personnel are available to deploy, the Air Force operates fixed-base control towers and RAPCONs, primarily in the United States. Within the airspace that has been delegated to the Air Force, Air Force controllers are required to provide a level of service equivalent to that provided by the host ATC organization. Consequently, external drivers determine the capabilities ATCALS must possess.

The world's ATC infrastructure is undergoing the greatest change since radar surveillance was integrated into the system. During the next 25 years, satellite-based navigation and approach guidance will replace much of the ground-based navigation and precision approach systems; digital exchange of information will replace voice communications; and aircraft will be permitted to fly optimum trajectories with few constraints. With some of these changes already taking place, the Air Force's entire ATCALS infrastructure must evolve.

If the Air Force fixed-base ATCALS infrastructure does not keep pace with the modernization under way in the United States and host nations, its facilities will not be postured to provide the level of service it agreed to provide when airspace was delegated to these fixed-base facilities. Air Force control of airspace will be revoked, along with its ability to train and to ensure that its controllers and maintenance personnel are capable of supporting contingency and wartime operations. Moreover, the Air Force's deployable systems must also evolve to provide the same services that host nations provide. They also must be capable of interfacing and integrating into the TBM systems of the future.

It is imperative that the Air Force modernize its deployable ATCALS infrastructure to ensure that it maintains an effective capability to support contingency and wartime operations like Desert Shield and Desert Storm.

The Air Force also must modernize fixed-base ATCALS to ensure that its facilities are capable of providing a level of service equal to the service provided in host nations. If not, airspace will be withdrawn and the Air Force will not be able to maintain a cadre of trained and proficient controllers and maintenance personnel who are available to deploy.

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Chapter 14—Datalinks

The study recognizes the importance of datalinks throughout the military, with particular recognition of their role in both civil and military aircraft operations. Datalink transmission provides a substantial improvement in the effectiveness of information transfer, greatly reducing the errors and confusion associated with voice transmission. Moreover, the efficiency is similarly much greater, probably to a factor of 100, especially in transfer of target location and character data.

Efficiency is particularly important. Much of the data (such as frequency changes and target locations and characteristics) need not be transmitted through the aircrew, but can be direct computer-to-computer communication, so that confusion is reduced and the aircrew's attention can be devoted to more important matters. Furthermore, the very constrained communication bandwidth available to the military is being eroded by the commercial "sale" of frequency spectrum.

Finally, the C^2 effectiveness of Air Force aircraft (scheduling, mission-following, target assignment, battle-damage assessment, etc.), whether in combat or support roles, is significantly enhanced by the use of communications between elements. Data communications is key to C^2 in an environment laced more with digits than with narrative.

14.1 SERVICES OF THE DATALINK

The services of datalinks related to GATM include the transfer of navigation-related data (such as waypoints), position reporting for ATC, separation assurance/collision avoidance, and other ATC-related information (such as flight clearances, NOTAMS, weather updates, routing and speed changes, and frequency changes). The Air Force can benefit from all these and, in addition, use datalinks for mission following, retasking, target data, formation flight, and military-unique C^2 traffic.

Much of the thinking the committee witnessed was stovepiped. The individual development and introduction of datalink systems into Air Force aircraft has been proceeding over recent years with little consideration for satisfying multiple needs with a given solution, for interconnecting data flows through gateways, or for viewing the entire information transfer function as a network problem satisfied by a variety of physical means. The problem becomes even more complex when similar stovepipe ATC systems are considered.

14.2 AIR FORCE DATALINK SYSTEMS

The Air Force has long recognized the tremendous potential of communications datalinks to improve information throughput and understanding and to enable electronic integration of data into other platform systems. Nevertheless, the incorporation of datalinks into Air Force aircraft has a miserable past. Datalinks were incorporated in interceptor aircraft in the late 1950s, yet nearly 50 years later the Air Force have not progressed to a substantial use of data transfer.

TADIL J has been identified as the DoD primary datalink and is being procured for most Air Force platforms in the near future. The challenge is to provide some structure to manage these datalinks to ensure interoperability of datalinks among the military Services and multinational users. As we enter the datalink requirements world of global air navigation, this challenge will become ever greater and even more essential.

ASD/C³I recognized the need for a coordinated approach to the datalink family and developed a JTDLMP. This plan establishes a “J-series family” of tactical data links (including TADIL J, Link 22, and the variable message format) based on TADIL J messages and/or data elements as the initial step toward achieving the goal of allowing an interchange of messages that would be independent of specific communications media. The JTDLMP states, “A major goal of this plan is to standardize C⁴I messaging and data elements used to provide a seamless, flexible data link environment.” This goal also clearly has relevance to global air navigation operations.

The JTDLMP and the hierarchy of message development that it describes provide an important tool to maximize joint and combined combat capability by aiming to create a seamless, interoperable data exchange environment. Realistically, though, gateways are a fact of life because of the different media used by the Services. We also know historically that gateways can be an impediment to interoperability unless they are supported by extremely detailed data-forwarding rules and protocol documents. We believe that gateways can be used to satisfy the global air navigation requirements, both inter- and intraregion.

Examples of questions that need to be asked include:

- What are the IERs between the affected players, and how will they be satisfied? IER development requires an analysis of *who needs* specific information, *who has* that specific information, *how* it can be transmitted, and *how* it needs to be presented to the user.
- What are the interoperability requirements between datalinks and supported systems and how will they be satisfied?
- Have the data-forwarding requirements/message translation/data-forwarding rules between the datalinks been defined?

14.2.1 The Joint Tactical Information Distribution System

JTIDS is a high-capacity digital and voice information distribution system that provides position location and navigation, user identification, secure, and jam-resistant communications. It is in use for TADIL J. JTIDS is a line-of-sight system that uses a nodeless, TDMA frequency-hopping architecture in the UHF band (960 to 1251 MHz). The MIDS low-volume terminals provide the same functionality but at much less cost and weight with state-of-the-art technology. MIDS is a five-nation development program, and terminals will be available in FY99/00 to start outfitting most DoD platforms. Combat air forces platform implementation plans call for the remaining air defense F-15s and C² platforms to begin installation first, followed by other fighters, then bombers. Several initiatives are being worked to accelerate these schedules.

14.2.2 Improved UHF Demand-Assigned, Multiple-Access Satcom

JCS established the UHF DAMA requirement due to the tremendous demand for UHF satcom. DAMA allows access on demand and priority, with unused channels free for use by others. Combat air forces alone will procure and/or upgrade 2,076 ground terminals and 279 airborne terminals (the Airborne Integrated Terminal).

14.2.3 Multimission Advanced Tactical Terminal (MATT)

The MATT provides near-real time, over-the-horizon threat data for a variety of airborne platforms. It simultaneously receives and processes intelligence reports from the Tactical Receive Applications, Tactical Data Exchange System Broadcast (TADIX-B), and the Tactical Information Broadcast Service.

14.2.4 Improved Data Modem (IDM)

The IDM provides targeting information to equipped aircraft through use of a programmable modem/processor developed for use with existing platform radios. It connects with Air Force and Marine Corps ground forward air controllers to provide targeting information for CAS and High-Speed Anti-Radiation Missile targeting information for suppression of enemy air defenses (SEAD). Forty F-16 Block 40s are currently equipped and more will begin fielding in FY99. The F-16 Block 50s are equipped for SEAD and Rivet Joint, and the EA-6B integration is under way as well. In addition, there is a recent requirement for extending IDM to JSTARS.

14.2.5 Position-Locating Datalinks

With the introduction of accurate GPS information in military aircraft, several attempts have been made to use it to improve the tactical air picture. Situational Awareness Beacon With Reply (SABER) and SA datalink (SADL) are two examples of attempts to capture platform location data to improve the tactical picture with position-locating datalinks. SABER is a satellite-based reporting system; SADL is an extension of the Army's Enhanced Position Location Reporting System for aircraft applications. Both have demonstrated some capability to improve tactical SA.

14.3 CIVIL ATC-RELATED DATALINK SYSTEMS

14.3.1 Datalink Systems for Commercial Aircraft

The ground infrastructure that supports commercial aviation datalink communications today is the system developed for airline company and administrative communications: the ARINC ACARS in the United States and Canada, and the SITA Aircom system in most of the rest of the world. Line-of-sight communications are VHF; beyond-line-of-sight communications use Inmarsat Aero or HFDL. Inmarsat Aero service is offered by three consortiums: Skyphone, Satellite Aircom, and Skyways Alliance, each operating over the Inmarsat constellation and offering global coverage except for the polar regions. The only provider of HFDL service is ARINC.

Since thousands of aircraft are already equipped to use ACARS/Aircom (almost 5,000 are equipped with ACARS), and the ground infrastructure is already in place, basing new ATC datalink services on ACARS and Aircom allows relatively rapid introduction of those services.

ACARS and Aircom are character-oriented systems. The ICAO vision is to transition to a bit-oriented system; the ADS and CPDLC applications for oceanic airspace are bit-oriented. The AEEC developed a set of protocols to allow these bit-oriented applications to operate over the character-oriented ACARS/Aircom networks; these protocols are defined in ARINC Characteristic 622.

The ICAO vision is also to transition to an open system interconnect-compliant worldwide communications infrastructure for aviation use, the ATN, which is sometimes described as "Internet in the Sky," although in fact the concept includes both air and ground components.

Two principal ATC datalink applications have been defined for use in oceanic/remote airspace: ADS-A and CPDLC, discussed above. There are several versions of these applications now in place or under development. RTCA MASPS for the ADS and CPDLC applications are presented in RTCA DO-212 and DO-219 respectively. The FANS-1 implementation of ADS and CPDLC is based on DO-212 and DO-219, but incorporates some changes based on implementation

experience; these message sets are defined in the ATS system requirements and objectives (ATS SR&O) document developed by Boeing and subsequently supplemented by other airframers.

The ADS and CPDLC applications defined in the ICAO SARPs for the CNS/ATM-1 package are intended for use with the ATN, which is ICAO's planned communications infrastructure for aviation. These applications are significantly different from the ADS and CPDLC applications implemented in FANS-1. Several transition strategies have been proposed to allow FANS-1 and ATN systems to exist simultaneously. The ICAO ADS Panel is now investigating the question of how to transition from FANS-1 to CNS/ATM-1 (ICAO SARPs-compliant) applications.

14.3.2 Automatic Dependent Surveillance—Addressed

With the success of the ACARS datalink, the introduction of accurate GPS information, and the worldwide satellite voice communications capability, the next step was open-ocean air traffic monitoring using aircraft self-reports. This was demonstrated during the Pacific Engineering Trials conducted by Qantas, Air New Zealand, Cathay Pacific, and United Airlines, and is now operational. Sponsored by the FANS committee of ICAO, these trials demonstrated one way to provide open-ocean ATC where ground-based ASRs and SSR interrogators are not available. This technique of aircraft self-reporting to a specific operations/control center is called ADS (or ADS-A) since the reports are addressed to a specific control center.

Today, considerable work is being done in civil aviation to expand the use of datalinks. Besides ADS-A, CPDLC two-way datalink messages are also transmitted over the ACARS network through a series of gateways. There is considerable expansion in the use of satellites and HFDL to handle asset visibility, ATC, and surveillance. It would be appropriate for the military to learn more about civil datalink capability and investigate possible use of gateways to exchange military JTIDS traffic information with the civil air service providers.

14.3.3 Mode S as a Datalink

Both the military and civil air controllers use a common SSR system. The military calls SSR IFF. The civilian version of SSR is called the ATC Radar Beacon System (ATCRBS). The military IFF equipment uses modes 1, 2, 3, 4, and C; the civilian ATCRBS uses Modes A, C, and S. Civil Mode A is the same as military Mode 3 and is usually called Mode 3/A. Mode S, developed by civilians, is really a datalink with a 56-bit message. Mode S is a selective question-and-answer system, but all Mode S transponders also broadcast or squitter their unique aircraft identification once per second.

Civil aviation also uses Mode S as the communications link for TCAS. Because Mode S can be used with an omnidirectional antenna, individual aircraft can selectively interrogate each other within line of sight and develop the required information to support TCAS. Even though the military has not established a requirement for Mode S, it has identified a requirement for TCAS in many of its airlift and VIP aircraft and is therefore buying a lot of Mode S equipment.

14.3.4 Automatic Dependent Surveillance—Broadcast (ADS-B)

The introduction of GPS into Mode S-equipped aircraft and the understanding that GPS-derived positions are more accurate than radar positions soon led to the concept of broadcasting aircraft's geodetic position as well as identification on these periodic Mode S squitters. The Mode S message had to be increased to 112 bits to accommodate this extra information. This broadcast

style of self-reporting is called ADS-Broadcast. Since the broadcast location is referenced to WGS-84, it can be automatically displayed on any platform that receives it.

Although the surveillance function is the primary strength of ADS-B, the FAA is developing an ADS-B Avionics Management Plan, which is considering other ADS-B applications, such as enhanced collision avoidance functionality. To date, the military has shown little interest in ADS-B. The military is just starting to install Mode S and may discover other functional utility in time. Cost estimates for installing Mode S on tactical aircraft have not been accomplished. For tactical use, an encryption method would be required.

14.3.5 High-Frequency Datalinks

The civil aviation community has developed an HF DL capability for aeronautical use. It is intended primarily for use in oceanic airspace, since civil oceanic aircraft are required to carry dual HF radios for position reporting and other communication when out of range of VHF coverage. The HF DL capability can be added via an external modem, to take advantage of an existing capability on the aircraft, or through a new radio. The initial use of HF DL has been for airline company communications, but many airlines, as well as ARINC (the HF service provider) are advocating its use as an oceanic ATC datalink to support ADS and CPDLC applications as well, and waypoint position reporting trials using HF DL and other systems have been carried out.

ICAO approved the start of HF DL SARP development in March 1996, and tasked a Working Group to prepare the documents. The Working Group expects to validate the SARPs by December 1997, and will recommend ICAO adoption of the SARPs in the spring of 1998.

14.3.6 VHF Datalink

One of the principal outcomes of the 1990 ICAO COM/DIV meeting was the direction to pursue the development of improved air-ground communications systems that would alleviate the worsening communications congestion in the three VHF aeronautical bands. This led to the formation of RTCA SC-172 in 1991 with a charter to investigate and recommend spectrally efficient VHF digital air-ground communications systems that not only include data communication but also are compatible with digital voice techniques. In the fall of 1993, SC-172 reached consensus on the physical layer of such a new communications system, namely, a modulation scheme consisting of differential 8-ary phase shift keying (D8PSK) with raised-cosine spectral shaping operating at a channel rate of 31.5 kbps.

There are two alternatives for media access control: carrier-sense multiple access (CSMA) and TDMA. Both use the same physical layer previously agreed on. The CSMA scheme is referred to as VHF digital link Mode 2, also known as aviation VHF packet communications (AVPAC); the TDMA scheme is referred to as VDL Mode 3. ICAO has endorsed Mode 3 as the long-term solution to VHF spectrum congestion and for providing a VHF digital link (data and digitized voice) capability, but other solutions continue to be pursued in worldwide aviation.

There is also a VDL Mode 1, which uses minimum shift keying at a 2,400-bps channel rate over a standard analog 25-kHz channel-width radio. This modulation is also used in the physical layer of the ACARS datalink protocol. ACARS is widely used by commercial aircraft, primarily for aeronautical operational control and airline administrative control, but it is also used for predeparture clearances and to support ATS applications in FANS-1. Mode 2 is the planned upgrade to Mode 1 to support the AVPAC protocol.

A self-organizing TDMA (S-TDMA) scheme, also VHF-based, is being advocated by Sweden and other European countries as a potential air-ground datalink. S-TDMA has been designated Mode 4 by ICAO. S-TDMA, sometimes known as “Swedish TDMA,” was suggested several years ago by the Swedish CAA for various ATC datalink applications, particularly those combining ADS-B and differential GPS for precision landing applications. The S-TDMA transceiver is designed to operate in the 120- to 150-MHz band of the VHF spectrum. The system can operate on up to 16 frequencies, each constituting a 25-kHz channel. The Swedish scheme would require a GPS receiver, a CMU, and a new digital VHF radio. S-TDMA frame structure is not compatible with the TDMA frame structures developed by RTCA.

14.3.7 Inmarsat

Inmarsat has provided data and voice communications via satellite for many years and, in fact, has been used in civil and military aircraft as well. The Inmarsat aeronautical system provides L-band voice and data communications at rates up to 10.5 kbps. It is the only system certified as beyond-line-of-sight ATC datalink or to provide direct pilot-to-controller communications beyond line of sight. Commercial airlines that fly oceanic routes are installing multichannel high-gain Inmarsat Aero equipment to support passenger communications as well as oceanic ATC.

The evolving Inmarsat C aircraft equipment⁵ with a range of position reporting and operational message capability is compact, with small antennas. Operating on L band (1.5 to 1.6 GHz) at 1,200 symbols per second, with a data rate of 600 bps, the system is available from 70° north latitude to 70° south latitude. Extensive use in Desert Storm proved its value to military aircraft and ground forces alike.

Aero-C offers a fast and relatively inexpensive way to implement an airborne datalink capability for larger DoD aircraft. Aero-C is an airborne extension of the land mobile system developed by Thrane & Thrane, a Danish corporation. The C service is separate from, and incompatible with, the Inmarsat aeronautical system. It cannot be used as an ATC datalink: it does not operate in an aeronautical safety spectrum band and its store-and-forward protocol cannot guarantee message delivery. Although Aero-C itself has been certified for airborne installation, Inmarsat will not pursue certification of the Inmarsat C infrastructure for ATC services.

14.4 TECHNOLOGIES FOR DATA TRANSFER

Several concepts and technologies offer escape from the stovepipe nature of existing thinking. It is important that the Air Force operational architect (Air Force Aerospace Command and Control Intelligence, Surveillance, and Reconnaissance Center) take an integrated view of the C² (including ATC) operational information problem. Similarly, the Air Force system architect (Air Force Communications and Information Center) and solution, to include the consideration of the following elements.

14.4.1 Global Grid (Networks and Gateways) (Networks vs. Point-to-Point)

Of special importance is the need for viewing the GATM communications solution as an element of a network of networks, with appropriate gateways to interconnect physical systems. GATM is

⁵ Example: Thrane & Thrane TT-3024A provides integrated GPS and datalink for full position reporting interface to the flight data system as well as operational messages.

just an element of the overall government communications system (and perhaps overall government and civil communications systems). In essence, the concept is similar to the Internet, in which a corporation's network satisfies an internal need, with appropriate secured gateways to the outside and to other networks.

Probably the greatest enabler to improving the effectiveness of data transfer associated with military and civil aeronautical operations is the Global Grid concept, and its embodiment as the Global Command and Control System. This concept views the military communications system as a network of networks, with appropriate gateways at the nodes. If the Air Force ties its aircraft to the ground node infrastructure, any aircraft can communicate worldwide using protocols that meet physical transfer requirements. The implications of this concept are immense, for now dissimilar equipment and waveforms could be utilized.⁶

14.4.2 Commercial Satcom Network Alternatives

The current satcom network for oceanic regions is the Inmarsat system. Its limited coverage (not over the poles), high cost of operations, and complex satellite antenna designs have resulted in limited commercial usage, but not in primary usage for the military aeronautical services. The military's reluctance to use a satcom network will be reduced as future satellite systems come online with multiple opportunities and competing systems. The near-term LEO satcom systems being developed commercially are going to provide competitive answers that will enable global communications with timely connectivity. The systems in Table 11 have received licenses, have ongoing engineering projects, have funding, and will be available in the near future. Figure 18, the Iridium system, is an example of an LEO constellation with voice and data connectivity "anytime, anyplace."

Table 11. *Emerging Commercial Satellite Communications Systems*

System	FOC	Type	Links
Iridium	Sept 98	LEO—66 satellites	Voice/data cross-links
Globalstar	Dec 98	LEO—48 satellites	Voice/data gateways
IC-Global	Jun 99	MEO—10 satellites	Voice/data gateways
Orbcom	Jan 98	LEO—24 satellites	Data store-and-forward
Starsys	Jun 98	LEO—12 satellites	Data store-and-forward FOC

Note: there are three more systems with licenses (Odyssey, Ellipso, and Constellation), but they have not shown significant progress leading to a firm FOC.

⁶ One example of the concept would be the ability to provide ATC data to the FAA network based on a secure JTIDS transmission, without the need to match the ATC datalink radio standard, simply by a translation gateway.

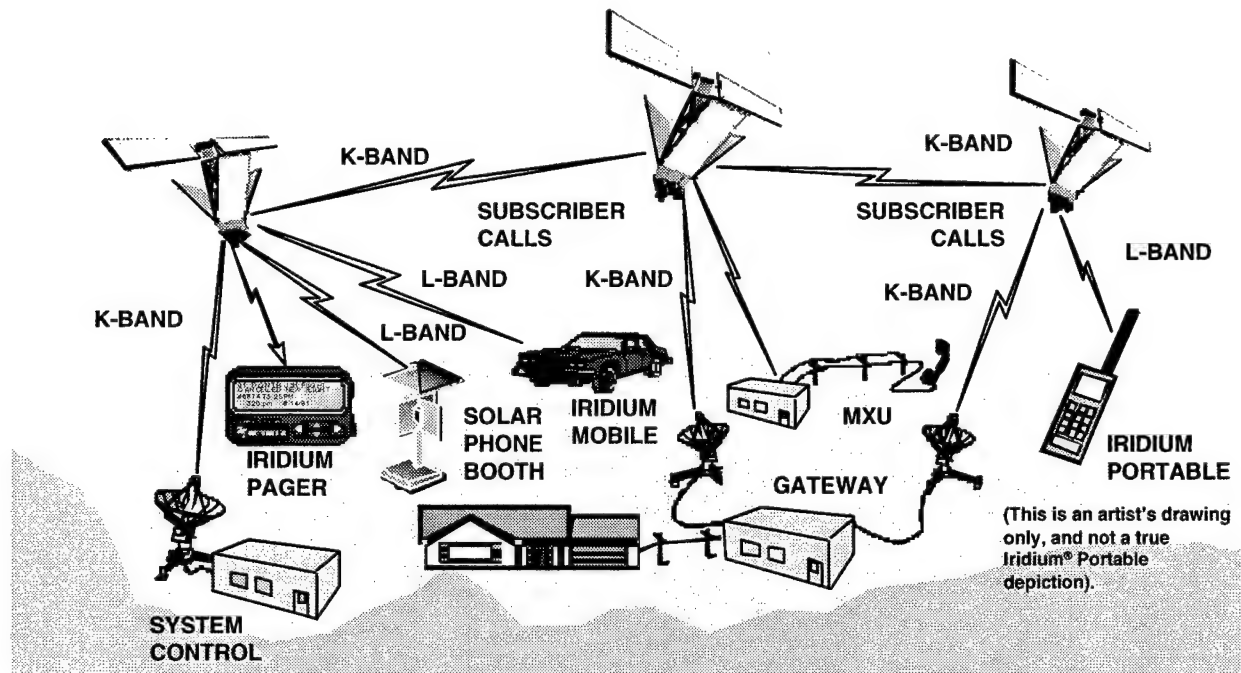


Figure 18. *Iridium Low-Earth-Orbit Satellite Communications System*

In addition, there are recently licensed systems that will be operational in the near future with far greater capacity. These wideband systems are progressing rapidly in all orbits of the communications industry. During 1995, American industry submitted 14 filings for approval to build and operate satcom systems from the geosynchronous (GEO) orbit with one filing for operations in LEO. The GEO filings were approved during April 1997 and the LEO filing during May 1997. These systems will have very high data rates with tremendous flexibility on beams and connectivity. Since then, there have been two more filings in the United States for LEO systems using wideband communications, competing with the GEO and LEO filings of 1995. Table 12 describes a few of these systems. Figure 19, the Celestri System Concept, reflects the mega-LEO constellation that provides wideband digital connectivity “anytime, anywhere.”

Table 12. *Future Satellite Communications Systems*

System	FOC	Type	Links
Spaceway™ (Hughes)	2002	GEO—20 satellites	Ka band voice, data, video
Astrolink (Lockheed Martin)	2002	GEO—9 satellites	Ka band voice, data, video
Cyberstar (Loral)	2002	GEO—3 satellites	Ka band voice, data, video
Teledesic (Boeing)	2002	LEO—288 satellites	Ka band voice, data, video
Celestri (Motorola)	2001	LEO—63 satellites	Ka band voice, data, video

The tremendously rapid technology growth in telecommunications will lead to the ability to exercise these new satellite constellation systems in new and innovative ways. The ability to communicate across international boundaries with reach-back across the oceans will enable new

uses for GEO and LEO systems to include the network of networks that can tie the aeronautical complex together. By using these capabilities, the total picture can be available for all nations at any instant in time. Navigation, surveillance, and landing can be executed with this global grid of communications when tied together with the global navigation capabilities of GPS. The diverse technologies developed with these satellite systems will reach across the communications field, with commercial forces driving the competitive pricing and manufacturing strengths.

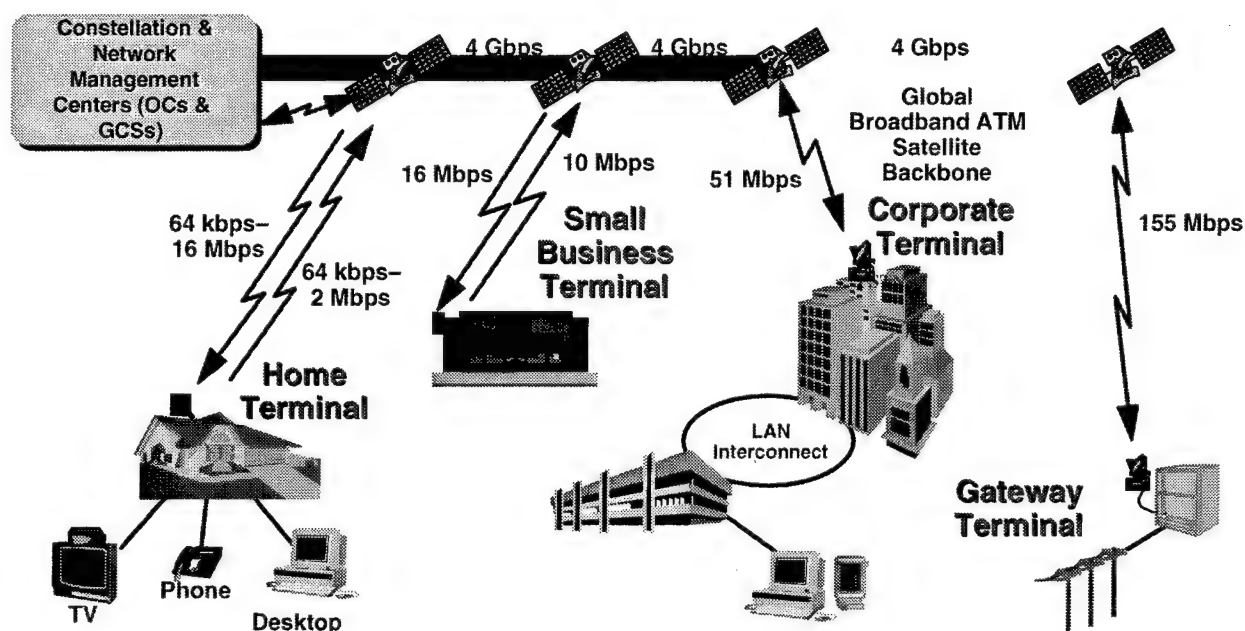


Figure 19. Celestri System Concept

An example of future developments is the recently announced Celestri system, with 63 satellites in LEO with wideband capability. The industry will support this great business opportunity with a selection of small terrestrial terminals that will be able to provide 2 to 10 Mbps. A 22-inch phased-array ground terminal will be produced in quantity (around 20 million) with prices to the public well below \$1,000. Projections are that airborne antennas can be produced at a similar price.

The use of gateways and aircraft antennas to tie these robust systems together will provide aircraft with a grid of communications above them offering reach-back to any location on earth. This network of networks will enable continuous communications, constant surveillance, and precise landing when established as part of a GANS.

14.4.3 Digital (Software-Reprogrammable) Multimode Radios

Software-reprogrammable radios have been in development in the military for years. They can adapt to changes in frequency, signal structure (waveform), message structure, and crypto-

security through software reprogramming, even dynamically. Moreover, the equipment can be programmed for greatly simplified migration to the objective C² or ATC architecture.⁷

The technology, when mature, will make a notable advancement in communications similar to that already achieved in reprogrammable multimode radars. At this stage, the state of the art in programmable radios allows limited capability (lower-frequency bands through UHF, limited bandwidth) and further maturation, including a more robust operating system that can be certified for military (and maybe civil) aircraft by multiple contractor teams.

The Services are individually and cooperatively considering digital, software-reprogrammable, multimode multiband radios. With DARPA and Army involvement, the Air Force is developing a digital multimode programmable radio under the Speakeasy program at Rome Laboratory. The Navy has a similar program, ECIT/JCIT, with a somewhat different approach. The Army is developing the Future Digital Radio. There are also a number of commercial programs to develop such radios. The trend is to expand the performance envelope of this technology, and the Air Force should view reprogrammable radio technology as a key enabler of future systems of many forms, capabilities, and contractors, rather than a single program for a radio. The technology is not yet mature, and the opportunity for a radio that can be procured competitively is still a few years away.

At this writing, there is a move toward raising the multimode radio to the status of a Joint Program with the associated JPO. This study hails that move as key to expanding the development to other vendor bases, shortening the development cycle, and reducing cost.

Digital multimode radios should be viewed as an opportunity to satisfy multiple communications, navigation, and identification requirements (military and civil) in one reprogrammable multiple (simultaneous) mode radio, saving money, time, and critical space aboard Air Force aircraft. The reprogrammable radio should also be viewed as an enabler for the period migration to the objective system.

14.5 THE DATA TRANSFER VISION

It is critical to recognize that the military network is really a network of networks, or a network of networks of networks, many dissimilar, and that the aircraft datalinks are just a small piece of the functional picture. Gateways between equipment and networks are essential, but are implementable at reasonable cost with great payoff, allowing diversity in transmission systems that enhances survival ability because it complicates the enemy's countermeasures challenge. The current Air Force Air Operations Network is basically a voice system, dependent on point-to-point communications links. The Air Force is striving to evolve to a data communications network (of networks), which will greatly reduce the voice channel congestion. That network (of networks) is shown in Figure 20.

⁷ An example would be to program a capability for TACAN and GPS now such that TACAN later could be programmed out and WAAS or LAAS programmed in.

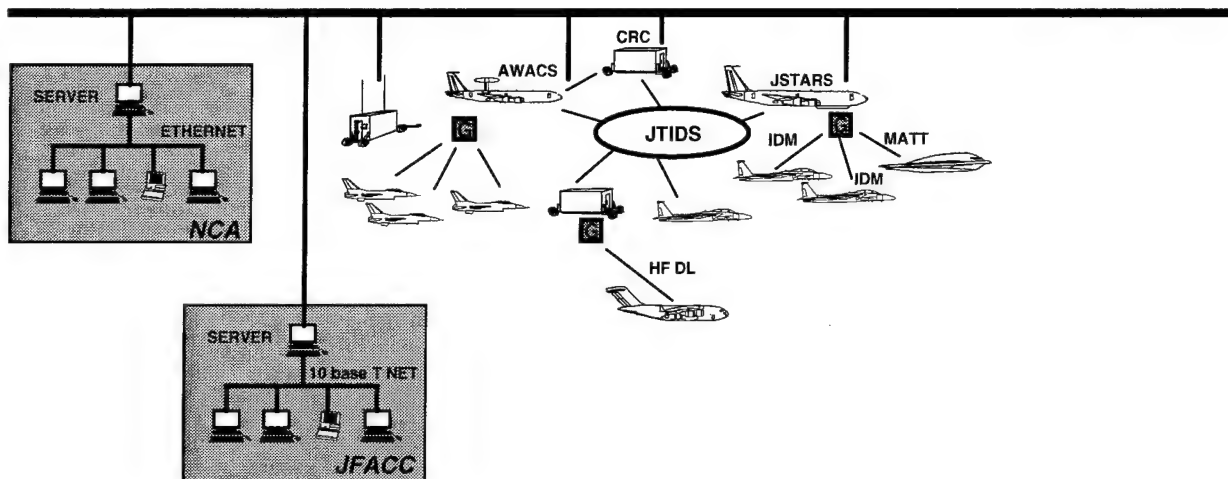


Figure 20. *Air Operations Network—Near Term*

It must also be recognized that a gateway to the civil ATC network can provide for the interchange between these systems, irrespective of the physical nature of the individual point-to-point links. Moreover, the GATM requirements, together with the evolution of LEO commercial satellite communications, suggests that this network concept be expanded to include those elements, as in Figure 21.

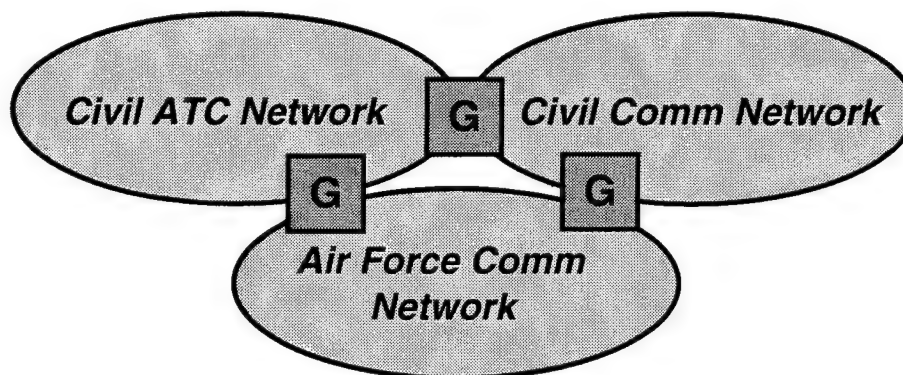


Figure 21. *Expanded Network Concept*

An element of such a network might be the ATN, ICAO's planned future communications infrastructure for the aviation community. The concept is being pursued primarily in Europe by the UK, and various trials and development efforts are in progress. Such a network might not be fully adopted, but the concept is sound, and ATN could be a significant element in an overall network solution.

But, just as the Air Force has established "building codes" that assure interoperability of the communications elements on the ground without unduly constraining equipment selection, so also must the aircraft datalink architecture be developed against standards which assure interoperability without dictating a single solution. Against these "building codes," a single manager for the Air Force air operations data architecture could ensure cost-effective data transfer as a

force multiplier, if not enabler, for future warfare while at the same time satisfying the communications needs of the worldwide ATC system.

The future air operations network (civil and military air communications) can be visualized by the example of Figure 22. The network concept assures the interaction of the key elements (Figure 21) while providing a cost-effective equipage solution essential in a highly constrained budget environment.

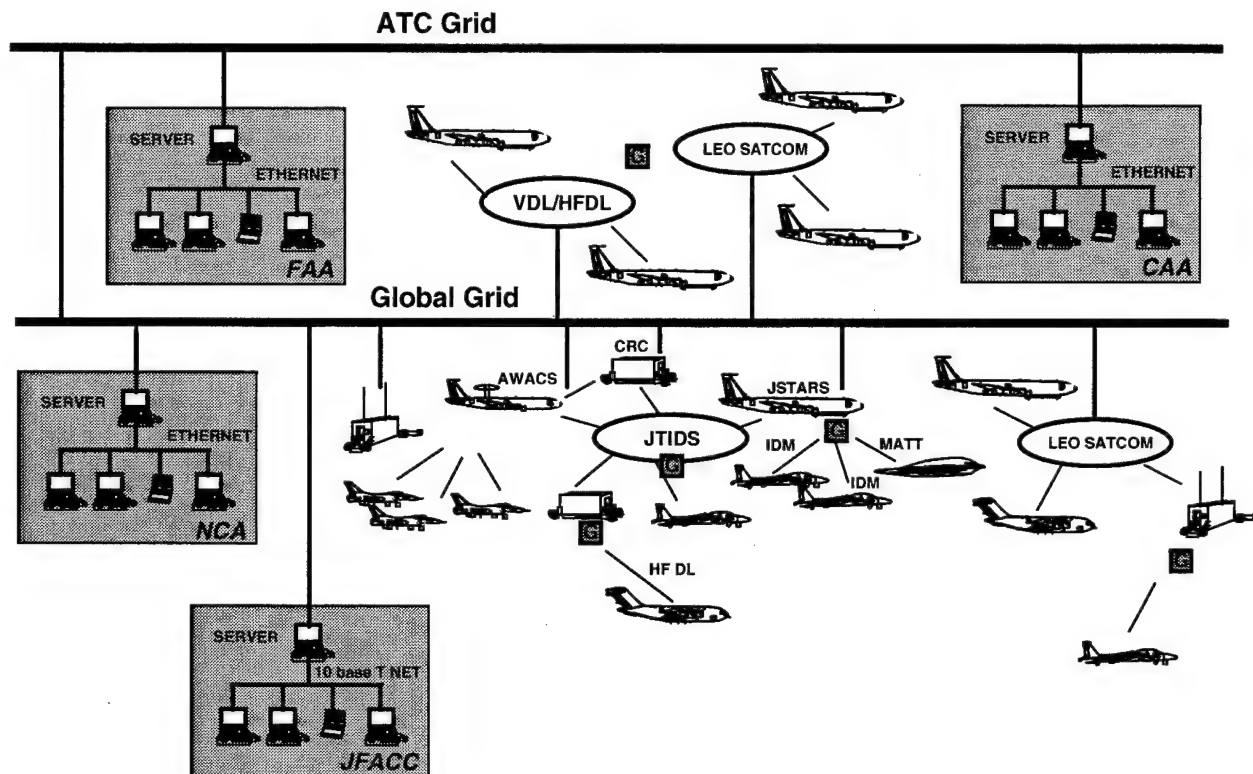


Figure 22. Air Operations Network—Far Term

On an aircraft, it is important that the datalink be integrated into the mission/weapon system to take advantage of the need for direct computer-to-computer communications essential to the transfer of the large amount of numeric data associated with modern navigation and targeting systems. Other communications must be provided to the aircrew displays, generally being formatted for display by the onboard mission computer. Other communications will be voice, and must directly access the aircrew. Appropriate accommodation of each mode is important to the architecture.

Finally, the Air Force must recognize that the network approach is a radical departure from the conventional point-to-point communications infrastructure and that it, as such, provides a significant improvement in robustness by offering diverse data paths. It brings with it a charge to assure that the ATC data is provided the communications priority it deserves, and that error protection and security be included in the selection of physical paths for transfer.

Chapter 15—GPS/INS Technical

15.1 INTRODUCTION

GPS is viewed by the FAA as the cornerstone of its future navigation service because of its potential to meet all needs with a modest investment in augmentations while significantly reducing the FAA's annual O&M cost of \$170 million. Civil augmentations are designed to enable GPS to be used as a "sole means" system where the "sole means" performance requires sufficient robustness to support the aviation application without restriction, 24 hours a day, 365 days a year. The overarching requirements in achieving this robustness are "5 nines" (99.999 percent) of availability for the en route-through-nonprecision approach service; "5 nines" of availability for precision approaches in high-density airports; and "2 to 3 nines" of availability at low-density airports. The availability requirement includes providing the required accuracy with an assurance that the information is correct within specified bounds (that is, having required integrity) and sufficient continuity to avoid the conditions where controllers are required to vector many aircraft in the event of a widespread outage. Internationally, augmentations (compatible with U.S. augmentations) are in development to provide extra ranging sources and integrity monitoring. Until sufficient robustness can be demonstrated, civil aviation authorities around the world are likely to retain a ground-based infrastructure.

One way to add robustness for the civil application—especially from the perspective of electromagnetic interference—is to provide the civil community with the C/A code on a second frequency, preferably L2, and remove the Selective Availability function. Both of these architecture changes were recommended by the Presidential Directive Document. Another alternative is to integrate GPS with other onboard navigation systems, such as an INS.

With the Boeing/INS (C/A code) integration, the availability of the fault-detection function is shown in Table 13. From this table it can be seen that RNP-1 has an average availability range from 0.993 to 1.0 (that is, > 0.99999) as a function of the number of satellites and RNP-0.15 (this is the nonprecision-approach application). The average availability range is from 0.894 to 0.996 as a function of the number of satellites. As the number of satellites drops below 24, the RNP-1 requirements are not satisfied, and even with 24 satellites the nonprecision approach availability is not achieved. Thus, the Boeing-type GPS/INS integration does not provide adequate availability for a "sole means" system. For civil users, the additional system availability can be provided using the WAAS additional geostationary satellites.

Table 13. FANS-1 GPS/INS RNP Availability With SA On

		RNP (nmi)				
		0.15	0.5	1	2	4
	HPL (nmi)	0.3	1	2	4	8
Number of Healthy Satellites	24	0.9964	0.9999	1	1	1
	23	0.9783	0.9989	0.9998	0.9999	1
	22	0.9450	0.9948	0.9981	0.9994	0.9998
	21	0.8942	0.8945	0.9934	0.9977	0.9993

Since performance improvements in the ranging accuracy also enable equivalent integrity improvements, military (PPS) users can achieve a high level of availability using the 24-satellite GPS constellation. DoD GPS-equipped tactical aircraft currently have PPS GPS and INS avionics. DoD transport aircraft are equipped with dual GPS/INS avionics. A RAIM integrity function (which requires at least five satellites) is not provided. This chapter assesses the performance a PPS GPS/INS architecture in performing the integrity-monitoring function using the P(Y) code performance without the use of civil augmentation signals.

15.2 TECHNICAL PERFORMANCE

The proposed navigation architecture for the military-only GPS capability is based on the integrated PPS GPS/INS avionics package for GANS. This section describes the expected performance of this architecture and identifies its operational implications. GPS/INS availability depends strongly on the type of integration, the number of states in the Kalman filter, and the accuracy of the onboard database that describes the earth's gravity field. The states need to include X, Y, and Z of the aircraft's center of gravity; rate of change of the X, Y, and Z; attitude (pitch, roll, and heading); and rate of change of orientation of the aircraft about the three axes of rotation.

Table 14 lists the key civil requirements and the predicted performance of the architectures identified in this section. In the en route airspace, the INS is continually updated by a self-monitored (that is, RAIM) GPS receiver. In the event that the GPS RAIM function is lost, the navigation continues for a short period. If dual INSs are available (as in transport aircraft) a 2 of 3 can increase availability depending on the quality of the INS. The key civil requirement to meet a sole-means capability (that is, to preclude operational constraints) is stated in AC 25.1309-1A, which requires that the loss of navigation and integrity functions have a probability of less than 10^{-5} in one hour of operation. For a 10-hour oceanic flight, this requirement would be 10^{-6} per hour. This requirement is not met with a conventional GPS integration scheme, but can be met with the GPS integration scheme described in paragraph 19.3.

At unmonitored landing areas, in the approach mode, the key precision approach requirement is to identify conditions when the vertical position error is less than 15 m (this limit is being considered by the FAA for CAT I WAAS operations). RAIM is used to detect out-of-tolerance

conditions. When RAIM is available (indicating operation within tolerance), the INS is updated and used for landing guidance. In the proposed architecture, it is planned to have a self-monitored GPS update the INS, as in the en route case. The GPS output is used as long as the RAIM function is available and the position measurements are below a threshold. In the event that RAIM is lost, or the position measurement exceeds the threshold, the navigation function is provided by the INS for TBD seconds (refer to Section 19-6 for INS performance). Rate-changing errors will be detected by applying RAIM separately for range and range-rate measurements. Many GPS integrity anomalies are clock jumps, which, if they are large enough, could easily be detected by an inertial system. However, slowly varying clock or ephemeris errors would not be detectable. In this concept, the INS enables the aircraft to continue the approach.

At monitored landing areas, a locally monitored differential signal is used to improve the accuracy and integrity. The FAA has developed an equation for the vertical alert limit:

$$5.33 \times \text{VDOP} \times \sigma_{\text{RANGE}}$$

The value must be less than 15 m. For a locally monitored differential signal, a σ_{RANGE} of about 0.4 m could tolerate a vertical dilution of precision (VDOP) of 7, which yields an availability of about 0.999, suitable for a CAT I landing system at a low-density airport. The availability can be increased (for high-density airports) by improving the GPS satellite constellation availability, or adding GEO ranging sources or pseudolites.

Table 14. Architecture Performance

Parameter	Civil Requirement		Predicted Performance	
	En Route	Precision Approach	En Route	Precision Approach
Accuracy	Currently 4 nmi, 2σ ; in future may be 1 nmi, 2σ	WAAS spec reqmt is 7.6 m vertical, 2σ ; ILS CAT I reqmt is 4.3 m vertical, 2σ	1 nmi achievable but depends on maximum INS coasting time	Depends on geometry and pseudorange error (for 1.5 m, 1σ range error and VDOP<2 accuracy is 6 m)
Integrity	$P_r\{HMI\} < 10^{-5}$ to 10^{-7} per flight operation; for a 1 nmi RNP the horizontal protection limit is 2 nmi	$P_r\{HMI\} < 10^{-7}$ per approach (interpreted as a vertical protection limit of 15 m)	RAIM/Inertial can provide 10^{-7} per hour when available	VPL is set at 15 m
Availability	Depends on acceptability of operation restrictions to satisfy continuity requirements	Loose requirement that depends on operation; single ILS provides 0.9915 in U.S.; a value between 0.95 and 0.99 for unmonitored airports and >0.9999 for locally monitored airports	TBD	TBD
Continuity	$P_r\{\text{loss of nav}\} < 10^{-5}$ per flight operation	$P_r\{\text{loss of PA}\} < 4 \times 10^{-5}$ per 150-second approach	$P_r < 10^{-5}$ when 3 sources; $P_r < 10^{-3}$ when 2 sources	Probability of unexpected loss of a satellite I 150 s is about 10^{-5}

15.3 CAT I PERFORMANCE WITH GPS/INS USING PV-RAIM

Although a GPS/INS integrated solution can meet the accuracy, integrity, and reliability requirements for en route and terminal area navigation, CAT I accuracy has not yet been demonstrated. A new integrity-monitoring algorithm, designed to take advantage of the PPS available to DoD users, shows promise of being able to meet CAT I landing requirements; the algorithm is described in this section. This capability would enable a CAT I space-based precision approach and landing system to be provided for DoD users based on existing (and planned) installed avionics.

The integrity-monitoring techniques developed by civil users of GPS rely on a combination of ground-based integrity monitoring (for example, by LAAS reference station) and RAIM in the receiver using differentially corrected GPS solutions. Both of these methods have limitations—the LAAS integrity message is available only at equipped airports, and conventional RAIM methods are functional only when good satellite geometry is available.

Conventional RAIM techniques developed for civil users concentrate on performing an integrity check on the vertical position error (VPE) using redundant satellite (pseudo-range) observations. The performance of the RAIM algorithm is a function of the accuracy of the measurements (1-sigma), the protection level to be achieved (VPE) and the integrity-monitoring geometry (DVDOP). With the proposed control segment accuracy improvements under the AII, the PPS pseudo-range accuracy will be equivalent to or better than that available with civil augmentation services. The integrity-monitoring response time within the control segment and through the satellite broadcast will also be improved (to minutes rather than hours).

The conventional RAIM techniques are excellent for detecting step errors in the GPS satellite signals. However, they are unable to detect slowly varying errors. For PPS users, it is possible to implement an enhanced RAIM function that can reliably detect both step functions and slow error drift rates (<0.1 m/s). This is achieved through addition of “velocity” RAIM to detect drift rate errors using the delta-range observations, and pseudo-range smoothing using carrier phase data to improve the performance of the position RAIM solution. It should be noted that PV-RAIM is not possible in the presence of Selective Availability, as the “high-rate” error terms in Selective Availability do not allow for slow drift rates in the satellite errors to be detected.

With the PV-RAIM algorithm, a residual check is performed on both the “velocity” residuals (using the delta-ranges) and the smoothed “position” residuals, using the standard RAIM geometric equations. Since it is hardest in either case to detect errors in the vertical dimension, the performance on detecting vertical position and drift-rate errors is the highest concern. The ability to detect these errors becomes a function of the integrity geometry (DVDOP), which is computed based on the assumed 1-sigma measurement errors, the allowed probability of missed detection (PMD), the vertical position error (VPE) and the allowed false alarm rate (PFA). With conventional RAIM, the false alarm rate equates to a continuity of service function during an approach and must be set at a very low level. With the proposed PV-RAIM solution, the false alarm results only in an update’s being discarded from the INS calibration. Since the INS can operate within the specified limits for minutes without an update, PFA can be set at a much higher value than previously allowed.

The PV-RAIM integrity coverage that could be provided for PPS users was simulated based on the following assumptions:

- The vertical accuracy must be assured to <15 m and <0.1 m/sec (with a probability of missed detection of 0.001) before a GPS update can be applied to the INS
- L1 and L2 pseudoranges and deltaranges are available to an accuracy of 1 m (1 sigma) and 0.5 cm/sec (1 sigma) respectively
- Enhancements are made in the control segment to reduce bias errors from clock drift and ephemeris to less than 1 m (errors of less than 80 cm are anticipated based on the space/control segment contribution when AII or Autonav is implemented)
- The INS can maintain accuracy over short periods (<2 minutes) with a drift rate of better than 0.1 m/sec

The goal of the Method B RAIM approach is to initialize the INS at the “top” of the approach glide path. Once the INS is initialized with a validated position and velocity vector, the aircraft uses INS only (cross-checked with redundant units) while flying down the approach path. The purpose is to proportion the integrity checks, GPS updates, and inertial error propagation so that when the aircraft reaches decision height the calibrated INS error should still be within the allowed error limits for a CAT I approach.

Based on the previous assumptions, the “velocity” check on the PV-RAIM solution requires that integrity geometry (DVDOP) of less than 6.5 be available to assure an integrity check if a vertical drift rate of >1 m/s is detected. A simulation showed the DVDOP distribution with the current GPS satellite constellation averaged over time and geography. Based on this simulation, with a DVDOP of 6.5, the V-RAIM algorithm would enable an INS update 50 percent of the time and would be available roughly 95 percent of the time with the current GPS constellation (see Figure 23). A typical DVDOP coverage plot for the GPS constellation is shown in Figure 24.

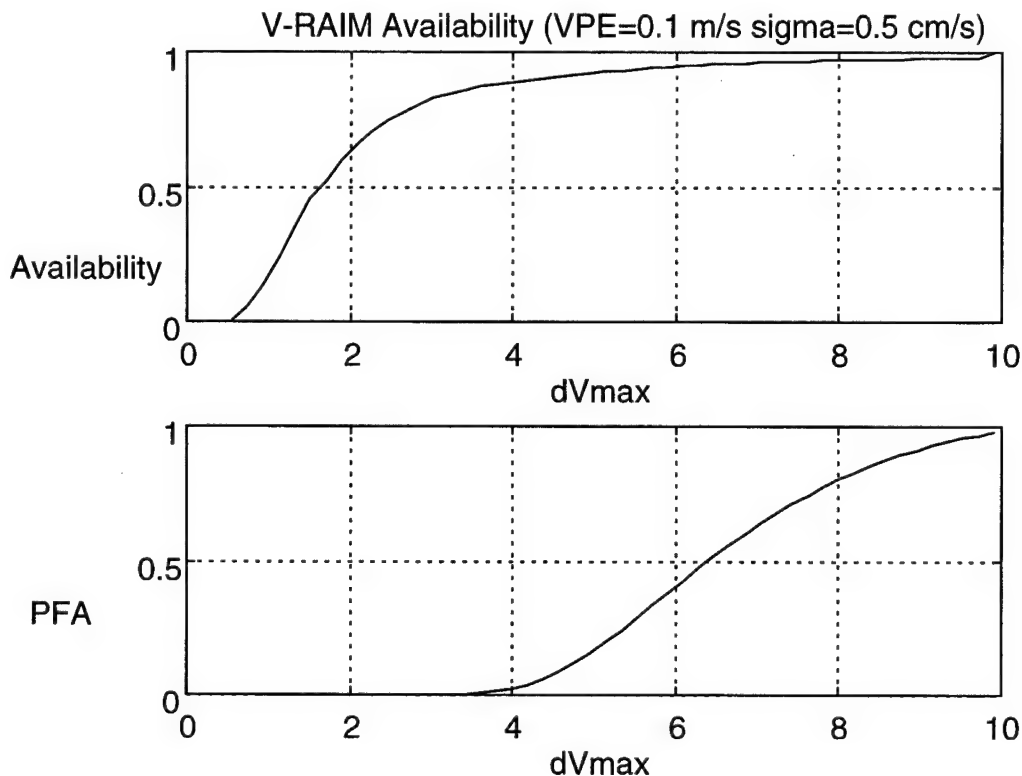


Figure 23. VRAIM Availability

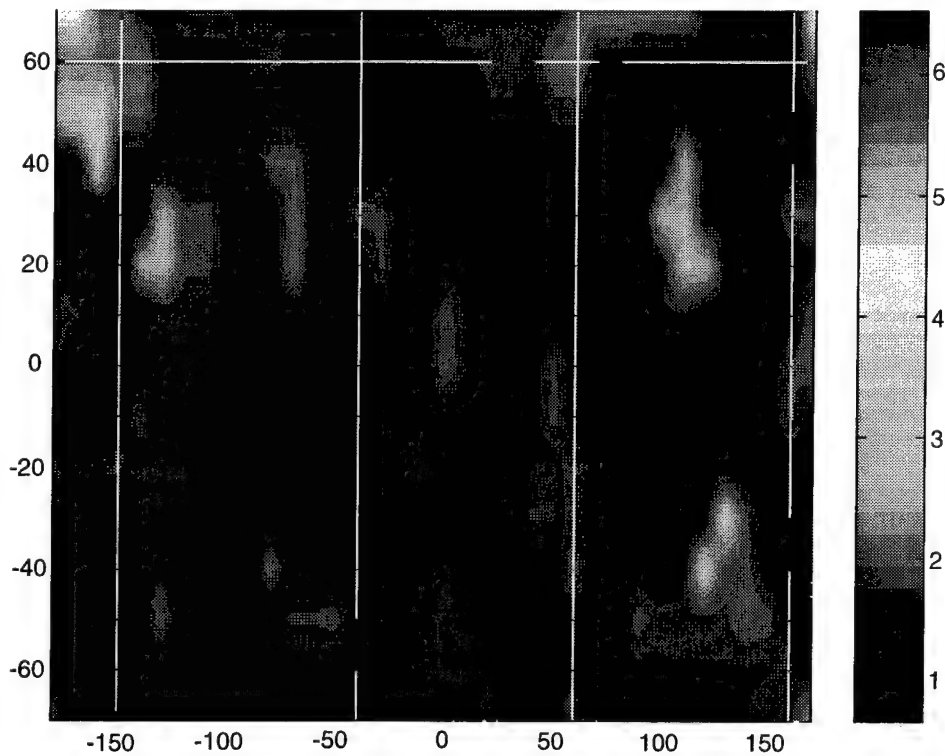


Figure 24. DVDOP

The smoothing of the pseudo-range observations, which slow down the update rate to the INS, also has a similar effect in improving the P-RAIM portion of the algorithm. This reduces the random (noise) errors on the residual detection parameter so that any errors in the measurements become much easier to observe. Under the same assumptions as the V-RAIM algorithm, a DVDOP of 15 can be tolerated if the INS updates are reduced to every 10 seconds, or a DVDOP of 5 if the updates are applied every second. In the first case, the geometry provides availability of 99 percent; in the second, 90 percent.

As shown in the figures, the outage holes for the integrity PV-RAIM geometry are limited to specific geographic areas at certain times of day, and generally last only tens of minutes. Since they can be predicted, it is possible to plan operations so that aircraft do not arrive to complete a precision approach during this time.

The improvement in integrity availability will be further enhanced if additional satellites are added to the constellation, improving the solution geometry. The geometry is also significantly improved if altitude aiding is used from an onboard radar altimeter using a precision terrain elevation database of the approach path. This reduces the number of integrity outage holes (in Figure 25 they are eliminated) and improves the PV-RAIM integrity monitoring availability.

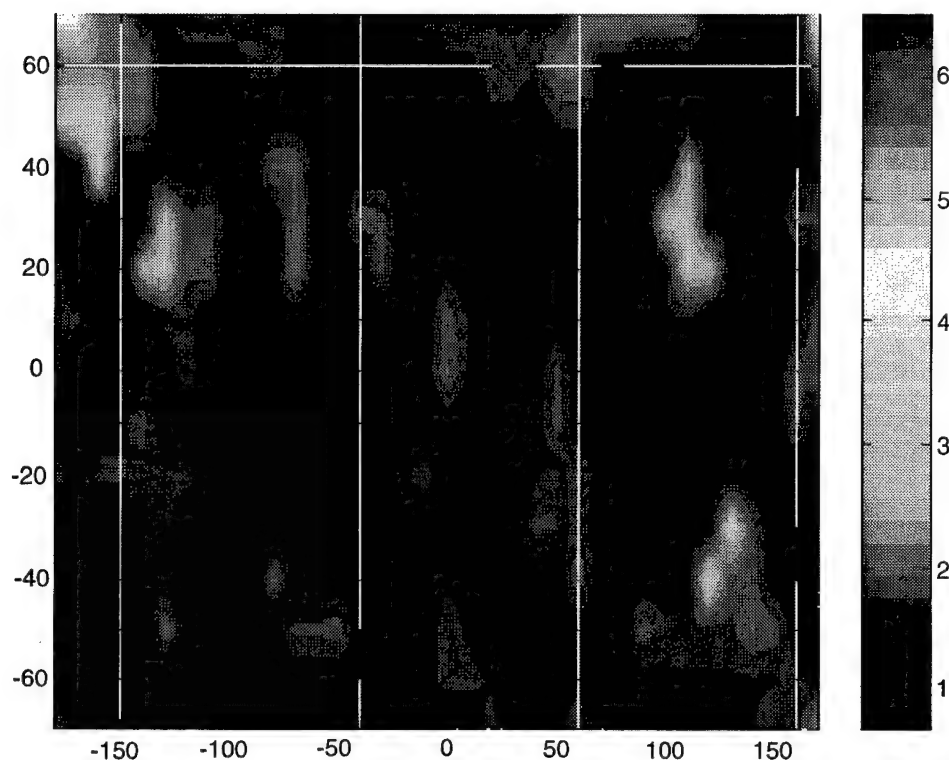


Figure 25. DVVDOP

Introduction of the PV-RAIM implementation into an integrated GPS/INS system will enable CAT I approaches to be performed *anywhere in the world*, relying totally on a space-based solution. At airports equipped with LAAS, the GPS/INS solution (with the addition of a VHF datalink) can be implemented, enabling CAT II/III precision. It is important to note that the PV-RAIM capability can be implemented in most *existing* P(Y) code user equipment through software upgrades. This would allow onboard avionics to be upgraded to provide this improved en route and precision approach capability.

15.4 OPERATIONAL IMPACTS

En route operations would be permitted whenever integrity and continuity requirements are satisfied, which would be most of the time with an integrated GPS/INS capability and 24 satellites. However, the destination airport would have to have visibility conditions consistent with approach guidance capability. At unmonitored airports, if the CAT I precision approach availability falls below 0.99 (for example, if integrity outages are expected), an alternative airport supported by a nonprecision approach would be needed.

At airports equipped with an LAAS, the integrity monitor and differential corrections provided through the VHF broadcast can be used to provide CAT I/II/III performance. To operate in this mode, military receivers will need to revert to C/A code tracking in order to correctly apply the differential corrections.

For operation near civil airports within the NAS, another way to improve availability, accuracy, and integrity is to use the WAAS, which will provide near-CAT I performance. The extra ranging sources, clock and ephemeris corrections, and integrity bounds can be used within the WAAS coverage area to improve the availability of the precision approach capability. Again, the GPS receiver must be operating in the C/A code mode to take advantage of this data.

To achieve the benefits of a WAAS/LAAS solution for military global operations, a P(Y) code augmentation system would be needed. A P(Y) WAAS could be implemented by carrying a broadband transponder on the next generation of civil WAAS satellites. A P(Y) LAAS would require development of a dual-mode monitor station—P(Y) and C/A—to enable interoperability of military and civil equipped aircraft (for example, CRAF).

In the near term, a useful navigation capability can be provided by a new method of integrating an all-in-view GPS receiver (with RAIM) and an INS, and providing 24 operational satellites. This architecture has an availability suitable for sole-means en route through nonprecision approach operations. However, if the constellation is allowed to degrade to 21 operational satellites, operational restrictions would be imposed occasionally, denying these military aircraft access to civil airspace. In addition, the availability of CAT I precision approaches will be 90 percent even with 24 satellites, resulting in severe operational restrictions. The availability can be improved to 99 percent when the improvements planned in WAGE and AII are implemented.

15.5 DUAL-MODE (SPS/PPS) NAVIGATION SYSTEM

Another option for DoD would be to transition to a GPS-based navigation function by using the civil augmentations where they exist and adding robustness by using the PPS capability in INS-equipped aircraft. This architecture requires a civil WAAS/LAAS receiver operating on the C/A code on L1 and L2, and a PPS/INS receiver, which would be used to validate the C/A-derived position report and support the tactical mission.

This approach offers the following benefits:

- Ability to use certified civil GPS avionics modules/cards to conduct en route through precision approaches in areas outside the theater of operations. This ensures RNP access to civil airspace and airports. (If the civil aviation community becomes reliant on GPS and the C/A signal is unavailable in civil airspace, it is unlikely that civil authorities would grant ATC clearance to military aircraft.)
- Ability to validate that the civil signal is not being spoofed. In the event spoofing is detected, the local ATC provider would be informed, perhaps in exchange for continued “right of passage” using the PPS capability.
- Ability to incrementally add availability for the PPS user in the theater of operations. A basic navigation and CAT I precision approach capability would be provided using a coupled GPS PPS/INS receiver having autonomous integrity monitoring. A wide-area WAGE/EDGE signal would enhance the availability (that is, by improving the availability of the integrity function). A local-area augmentation of the PPS signal transmitted on the secure communications datalink would further improve availability of the CAT I precision approach service as well as providing a CAT III-like landing capability. Extension to full CAT III civil-quality service would be limited by the certification of the datalink.

15.6 VERTICAL CHANNEL PERFORMANCE OF AN INERTIAL SYSTEM

The vertical channel of an inertial navigation system is known to be unstable. The vertical position and velocity error will increase exponentially with time (approximately), even if the inertial system is initialized with zero position and velocity errors. The reason is described below.

Consider a vertical accelerometer with its input axis along the Z axis. The equations that would be mechanized to compute the altitude of the accelerometer would be:

$$\ddot{h} - (2g_0 / Z_0)h = A - g_0 \quad (\text{Equation 1})$$

where Z_0 is an arbitrary initial point, g_0 is the gravity at Z_0 , and A is the measured specific force. If there is an error ΔA in A , then the differential equation describing the error in altitude can be written:

$$\Delta \ddot{h} - (2g_0 / Z_0)\Delta h = \Delta A \quad (\text{Equation 2})$$

The general solution of this equation is:

$$\Delta h = \frac{\Delta A}{\omega^2} [\cosh(\omega t) - 1] + \Delta h(0) \cosh(\omega t) + \frac{\Delta \dot{h}(0)}{\omega} \sinh(\omega t) \quad (\text{Equation 3})$$

where $\omega = \sqrt{2g_0 / Z_0} = 0.00175 \text{ rad / s}$

This equation will grow without bound due to an accelerometer bias, an error in the initial altitude estimate, an error in the initial altitude rate estimate, or noise. The initial altitude error is a function of the pseudorange error and geometry. By removing ionospheric delay and Selective Availability, DoD receivers using modern narrow correlator processing with carrier smoothing may generate pseudorange accuracies on the order of 1.5 m. The residual sources of error are the troposphere, clock, and ephemeris. In the future, errors may be reduced by adding on-satellite ranging corrections.

Assuming a 1.5-m, 1σ pseudorange error and a VDOP of about 2.3, a 2σ altitude error of 7 m can be expected. This accuracy would meet the current FAA WAAS requirement of 7.6 m. Figure 26 provides plots of this equation for three accelerometers bias values: 100 μg , 50 μg , and 0 μg . For all plots the assumed initial altitude bias is 7 m, and there is no initial altitude rate bias assumed. A 50- μg accelerometer bias is reported to be possible for an AHRS-quality accelerometer with GPS calibration.

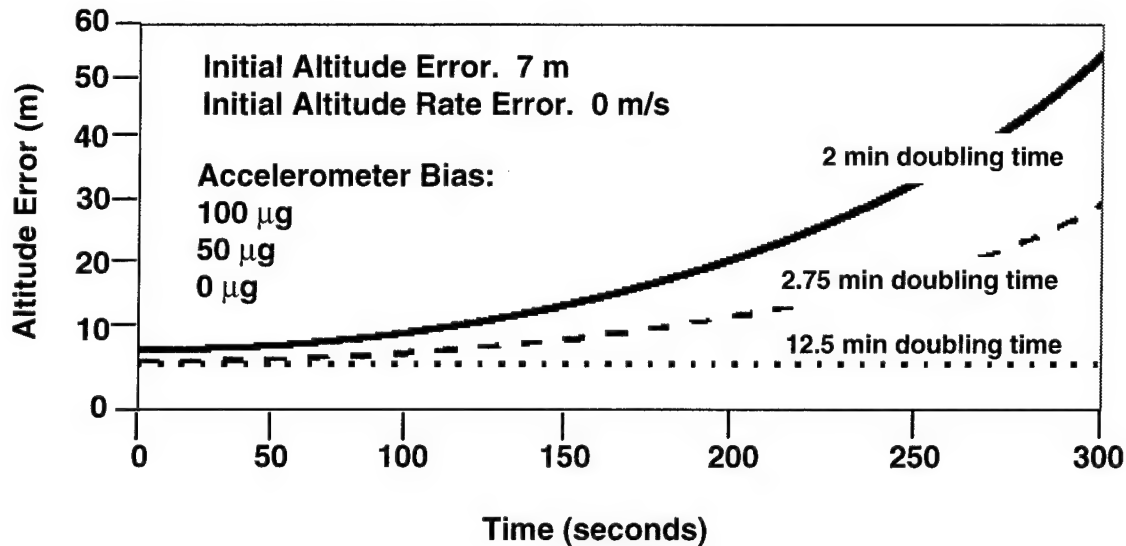


Figure 26. *Vertical Channel Performance*

Under the postulated scenario, the error in the vertical channel will exceed the protection limit of 15 m in about 15 minutes with a zero accelerometer bias. Additionally, if there is even a small initial altitude rate bias (e.g., 0.1 m/s) it will take 5 seconds to exceed 7.6 m error from an initial 7-m bias and under 1.5 minutes to reach the monitor alert limit.

Because of the vertical channel performance, it is unlikely that the INS can be used for more than a few minutes—which does not significantly increase the availability of the precision approach integrity function. The INS improves the continuity function but continuity is not a driver in the precision approach application because the probability of losing a satellite during the approach is already sufficiently small.

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Chapter 16—Airspace Deconfliction/Deconfliction Assurance

16.1 INTRODUCTION

Today, U.S. civil airspace surveillance, deconfliction/separation assurance and ATC is achieved by a combination of procedural means based on flight plans, ASR, and SSR using Modes A, C, and S. ATC communications is achieved by VHF and UHF voice. The current draft 3.0 of the NAS Architecture calls for significant changes in the surveillance and communications capability within the NAS.

The primary focus of the new NAS architecture will be shifting to aircraft self-reports, datalink and voice communications, and significant improvements in data fusion. The data fusion will integrate surveillance data from SSR, ADS-B, and air search/primary radar sources to provide a single report for each aircraft. This report will be placed on a network for use by appropriate applications. En route interior primary radars may be decommissioned when their functionality is replaced by imported weather data via NEXRAD. The land line surveillance communications protocol is being upgraded to ASTERIX, the European standard, to capture time tags on the data. The range of the terminal Mode S SSR will be extended, and data will be exchanged with en route facilities. The requirement for terminal area primary radar is expected to continue indefinitely.

These changes in NAS architecture will impact DoD aircraft that use the system and will also affect DoD as a service provider. The output of joint use radar (for example, ARSR-4 and DASR) will be available for civil and military applications. Gateways will be required to facilitate other information exchange opportunities. Some consolidation of infrastructure should be expected for both DoD and the FAA once better information exchange capability is operational. Likewise, in Europe a transition to Mode S as the SSR is in progress. The incorporation of Mode S in DoD aircraft will facilitate civil compatibility in both the NAS and in Europe.

An additional deconfliction function is provided by TCAS II equipment. This equipment uses the aircraft's Mode S transponders and is mandatory in the United States for passenger-carrying commercial aircraft. DoD aircraft, with IFF Mode C capability and no Mode S, will be seen by TCAS II-equipped aircraft (but not vice versa). TCAS II equipment also provides traffic alerts and resolution advisories (the required vertical maneuvers to minimize the risk of collision). These advisories are also data-linked to controllers for SA. In practice the resolution advisories are not always followed, in part because resolution advisories change with time and pilots appear to occasionally rely on their own perception of the threat. The latest version (TCAS II version 7) of the software will reduce the cases of undesired resolution advisories. In Europe, ACAS (the same as TCAS II version 7) will be required on passenger-carrying aircraft by 2005.

This TCAS capability is also used to support an in-trail climb/descent procedure in Pacific oceanic airspace. This procedure enables a trailing aircraft to identify a lead aircraft and coordinate (with ATC and the lead aircraft) a climb/descent through the flight level occupied by the lead aircraft. DoD aircraft that do not have TCAS cannot perform this in-trail procedure.

In oceanic airspace, separation assurance is provided based on approved flight plans and HF voice transmitted pilot position reports via a service provider. Because of communication delays and uncertainties in the reported position, large (that is, 50- to 100-nmi) separation standards are imposed, limiting airspace capacity. Reliable communications via satcom and an ADS capability

are being implemented to support reductions in the separation standards. RNP specifies a performance level, not a particular technology.

The U.S. aviation community is exploring the application of an ADS-B function wherein aircraft, surface vehicles, or obstructions can automatically and continually broadcast identification, position, altitude, and information describing the vehicle's intent. In the near term, this broadcast will use Mode S extended squitter format, the same as used by TCAS II version 7. This effort is specifically designed to capture the automatic reports from general aviation aircraft not equipped with TCAS II. Since the aircraft positions that are broadcast are referenced to the standard geodetic grid WGS-84, each platform, aircraft, or ground terminal that receives these line-of-sight reports is able to automatically display the reporting traffic in the vicinity.

The FAA is developing an ADS-B management plan based on the work of RTCA SC-186. The plan is intended to capitalize on community interest in air-to-air applications. ADS-B demonstrations are part of the FAA's Flight 2000 program. A summary and proposed schedule for selected applications is provided in Table 15, which is taken from a draft FAA report. Table 15 points out that the civil community may be developing specific applications to improve the efficiency of operations without the full expense of a TCAS II installation. For airspace users, the motivation to equip will be based on the level of service available and the benefits possible in any given airspace. These benefits will depend not only on the individual user's equipage, but also on the ground infrastructure and whether other users in the airspace are equipped.

The following assumptions pertain to aircraft, vehicle, and obstruction hazard equipage:

- In general, ADS-B user equipage will be voluntary. To facilitate voluntary equipage, demand-side incentive programs will be considered.
- For some applications, in certain airspace, ADS-B equipage may be required. Since the Mode S extended squitter is the same as used by TCAS II version 7, this should allow aircraft equipped with ADS-B to access airspace possibly reserved for TCAS-equipped aircraft.
- User equipage will be predicated on incremental benefits in capacity, efficiency, and safety.
- Certain benefits will be predicated on the implementation of a ground-based infrastructure.
- For users electing to equip with ADS-B and choosing not to make use of any additional ADS-B onboard applications beyond the basic surveillance function, only an ADS-B minimum system as defined in the MASPS is needed.
- The accuracy, integrity, and availability of the navigation data source and the datalink supporting ADS-B will be consistent with the needs of the operational environment.

16.2 IMPLICATIONS FOR DOD

The implication for DoD operations is constrained access to airspace and airports unless aircraft are equipped with TCAS II version 7 or ADS-B technology, including a cockpit SA display. In the United States, the ADS-B implementation will be built on the Mode S extended squitter function, which is already part of the TCAS II version 7 Mode S transponder. Even in Europe, ACAS is based on Mode S extended squitter. ACAS will be installed in passenger-carrying aircraft between 2000 and 2005. Likewise, Mode S will be a requirement in *all* EUROCAE aircraft by 2005. *U.S. aircraft equipped with TCAS II and Mode S-based ADS-B will meet the European standards and be interoperable in EUROCAE airspace.*

Alternative communication protocols are also being explored for the ADS-B function at ICAO and in Europe. Current ICAO plans call for ADS-B guidance material to be developed by 1999 but a target date for completion of standards (SARPs) and procedures (PANS) has not been defined. If the ICAO ADS-B protocol is other than Mode S, incompatibility would restrict those aircraft from operating in the United States. Several solutions involving simulcasting of traffic by the service provider or installing interoperable receivers are possible.

In addition to ATC operations, DoD aircraft can use an ADS-B function for military missions (such as air refueling and formation flying) but would require a secure encryption capability. Because of the uncertainty in the worldwide ADS-B protocol, coupled with the fact that DoD has not invested in Mode S technology except as associated with TCAS II for passenger aircraft, it is recommended that DoD actively participate in the definition of ADS-B in ICAO and plan for the implementation of a multifunctional cockpit display using ADS-B as one of its applications.

Table 15. Proposed Schedule for Selected ADS-B Applications⁸

MASPS Reference Number	Operational Application	Begin OT	IOC	Cargo FOC	Civil FOC
A.1.1	In-trail climb and in-trail descent in oceanic, remote, or domestic nonradar airspace	8/98	12/98	N/A	
A.1.3	Lateral passing maneuvers in oceanic, remote, or domestic nonradar airspace	6/00	6/01	N/A	
A.1.4	Stationkeeping in oceanic, remote, or domestic nonradar airspace	6/00	6/01	N/A	
A.1.10	Enhanced visual approaches in VFR conditions	12/99	6/00	N/A	
A.1.14	Facilitate closely spaced parallel approaches in IMC	6/99	12/99	N/A	
A.1.15	Enhanced visual acquisition of other traffic in the VFR traffic pattern at uncontrolled airports	12/99	6/00	N/A	
A.1.17	Airport surface SA (VFR-day & VFR-night)	12/99	6/00	N/A	

⁸ Source: FAA ADS-B Avionics Management Plan, Draft Version 2.0, 16 May 1997

MASPS Reference Number	Operational Application	Begin OT	IOC	Cargo FOC	Civil FOC
A.1.19	Enhanced visual acquisition of other traffic for "see-and-avoid"	12/99	6/00	N/A	
A.1.20	GNSS Enhanced Collision Avoidance System Traffic situational awareness in all airspace Conflict situational awareness (with Tas) in all airspace	6/98	12/98	12/99	
A.1.21	Collision situational awareness (with Tas and Ras) in all airspace	1/99	6/99	12/99	
A.1.22	ADS-B collision avoidance	1/01	9/01	12/01	
A.1.23	Surveillance enhancement for TCAS/ACAS in all airspace	1/99	6/99	N/A	
A.2.3	Application of "pseudo-radar" separation standards at airports without radar coverage	12/99	6/00	N/A	
A.2.10	Conformance monitoring during simultaneous parallel and converging approaches	6/99	12/99	N/A	

List of Acronyms

Abbreviation	Definition
A/J	anti-jam
AAC	airline administrative control
AC	advisory circular
ACARS	Aircraft Communications Addressing and Reporting System
ACAS	Airborne Collision Avoidance System
ADM	Acquisition Decision Memorandum
ADS	automatic dependent surveillance
ADS-A	ADS-addressed
ADS-B	ADS-broadcast
AEEC	Airlines Electronic Engineering Committee
AEF	Air Expeditionary Force
AFM	Airlift Flow Model
AIC	aeronautical information circular
AII	Accuracy Improvement Initiative
AIP	aeronautical information publication
AIT	Airborne Integrated Terminal
ALTRV	altitude reservation
AMJ	advisory material joint
AMS(R)S	aeronautical mobile satellite (route) service
ANC	Air Navigation Commission
ANG	Air National Guard
AoA	analysis of alternatives
AOAS	Advanced Oceanic Automation System
AOC	aeronautical operational control
APANPIRG	Asia/Pacific Air Navigation Planning and Implementation Regional Group
ARINC	Aeronautical Radio Inc
ARTS	automated remote tracking station
ASAS	Aircraft Separation Assurance System Subcommittee
ASC²A	Air Force Air and Space Command & Control Agency
ASR	airport surveillance radars
ATA	Air Transportation Authority
ATC	air traffic control
ATC CTSS	ATC control tower simulation system
ATCALs	ATC and landing systems
ATCT	ATC towers
ATCTD	ATC training device
ATD	advanced technology demonstration
ATM	air traffic management
ATN	Aeronautical Telecommunications Network
ATNSI	ATN Systems Inc.
ATS	air traffic services

ATS SR&O	ATS system requirements and objectives
AVPAC	aviation VHF packet communications
BRNAV	basic area navigation
C/AFT	CNS/ATM Focus Team
C/SOIT	Communications/Surveillance Operational Implementation Team
CAA	civil aviation authority
CAT	category
CCT	combat control team
CDTI	cockpit display of traffic information
CEAC	Committee for European Airspace Coordination
CJCS	Chairman of the Joint Chiefs of Staff
CMARPS	Contingency Mating and Ranging Planning System
CMU	communications management unit
CNS/ATM	communications, navigation, and surveillance/air traffic management
COE	common operating environment
COEA	Cost and Operational Effectiveness Analysis
COM/DIV	Communications/Operations Divisional
COTS	commercial, off-the-shelf
CPC	Controller-Pilot Communications
CPDL	controller-pilot datalink communications
CRAF	Civil Reserve Air Fleet
CSMA	carrier-sense multiple access
D8PSK	differential 8-ary phase shift keying
DAAS	DoD Advanced Automation System
DAB	Defense Acquisition Board
DAMA	demand-assigned multiple access
DAP	downlink aircraft parameters
DARPA	Defense Advanced Research Projects Agency
DASR	digital airport surveillance radar
DFS	Deutsche Flugsicherung
DGAC	Direction Générale de l'Aviation Civile
DGNSS	differential GNSS
DME	distance-measuring equipment
DoD	Department of Defense
DPG	Defense Planning Guidance
EANPG	European Air Navigation Planning Group
EATMS	European Air Traffic Management System
ECAC	European Civil Aviation Conference
EFIS	Electronic Flight Instrument System
EGNOS	European Geostationary Navigation Overlay Service
EPLRS	Enhanced Position Location Reporting System
ESC	Electronic Systems Center
ETVS	Enhanced Terminal Voice Switch
EUR/RAN	European Regional Air Navigation
Eurocontrol	European Organisation for the Safety of Air Navigation
FAA	Federal Aviation Administration

FANS	Future Air Navigation System
FAR	Federal Aviation Regulations
FFRDC	Federally Funded R&D Center
FIR	flight information region
FIS/ATIS	flight information services/automated terminal information service
FL	flight level
FM	frequency modulation
FMS	flight management system
FOC	full operational capability
FRP	Federal Radionavigation Plan
GAT	general aviation traffic
GATM	global air traffic management
GATO/MC²	Global Air Traffic Operations/Mission C ² SPO
GEO	geosynchronous earth orbit
GES	ground earth station
GNLU	GNSS navigation and landing unit
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HARM	High-Speed Anti-Radiation Missile
HFDL	high-frequency datalink
ICAO	International Civil Aviation Organization
IDM	Improved Data Modem
IER	information exchange requirements
IFALPA	International Federation of Airline Pilots Associations
IFATCA	International Federation of Air Traffic Controllers Associations
IFF	identification, friend or foe
IFR	instrument flight rules
IGEB	Intergovernmental Executive Board
IGIA	Interagency Group on International Aviation
ILS	instrument landing system
IMG	Implementation Management Group
INS	inertial navigation system
IOC	initial operational capability
IPACG	Informal Pacific ATS Coordination Group
ISPACG	Informal South Pacific ATS Coordination Group
JAA	Joint Aviation Authorities
JCAB	Japan Civil Aviation Bureau
JCS	Joint Chiefs of Staff
JRE	range extension
JROC	Joint Requirements Oversight Council
JTDLMP	Joint Tactical Data Link Management Plan
JTIDS	Joint Tactical Information Distribution System
LAAS	local-area augmentation system
LEO	low earth orbit
MAJCOM	major command
MASPS	minimum aviation system performance standards

MASS	Mobility Airlift Support System
MATT	Multi-Mission Advanced Tactical Terminal
MEO	medium earth orbit
MIDS	Multifunction Information Distribution System
MLS	microwave landing system
MNC	Major NATO Command
MNPS	minimum navigation performance specifications
MNS	Mission Needs Statement
MOA	Memorandum of Agreement
MOG	minimum on ground
MOPS	minimum operational performance standards
MRC	major regional conflict
MRS BURU	Mobility Resource Study–Bottom-Up Review Update
NAS	National Airspace System
NASPRO	NAS Plan Requirements Office
NASSRS	NAS System Requirements Specification
NAT	North Atlantic
NATO	North Atlantic Treaty Organization
NATS	National Air Traffic Services Ltd., UK
NATSPG	NAT Systems Planning Group
NAVAID	navigation aid
NBAA	National Business Aircraft Association
NDI	nondevelopmental item
NDTA	National Defense Transportation Association
NEXCOM	next-generation air-ground communications
NIMA	National Imaging and Mapping Agency
nmi	nautical mile
NOTAM	notice to airmen
OCS	Operational Control Segment
ODL	oceanic datalink
OJT	on-the-job training
P³I	preplanned product improvement
PALC	precision approach landing capability
PANS-RAC	Procedures for Air Navigation Services—Rules of the Air and Air Traffic Services
PAR	precision approach radar
PBFA	Policy Board on Federal Aviation
PDC	predeparture clearance
PDD	Presidential Decision Directive
PEM	Program Element Monitor
PGL	program guidance letter
PLSAG	Precision Landing Study Advisory Group
PMD	probability of missed detection
PODS	portable equipment of selected platforms
POM	Program Objective Memorandum
PPBS	Planning, Programming, and Budgeting System

PPS	Precise Positioning Service
PRNAV	precision area navigation
RAIM	Receiver Autonomous Integrity Monitoring
RAN	regional air navigation
RAPCON	Radar Approach Control
RC	raised cosine
RCP	required communications performance
RGCSP	Review of the General Concept of Separation Panel
RNAV	area navigation
RNP	required navigation performance
RSP	required surveillance performance
RTCA	Radio Technical Commission for Aeronautics
RTSP	required total system performance
RVSM	reduced vertical separation minimum
SA	Selective Availability
SABER	situational awareness beacon and reply
SADL	situational awareness datalink
SAI	Systems Architecture and Interfaces Subcommittee
SARPs	Standards and Recommended Practices
SEAD	suppression of enemy air defenses
SHAPE	Supreme Headquarters of the Allied Powers in Europe
SID	standard instrument departure
SITA	Société Internationale de Télécommunications Aéronautiques
SPD	System Program Director
SPO	System Program Office
SR&O	system requirements and objectives
SSR	secondary surveillance radar
STAR	standard arrival route
S-TDMA	self-organizing TDMA (Swedish TDMA)
SUA	special-use airspace
TAB	theater air base
TACAN	tactical air navigation
TADIL	Tactical Digital Information Link (Link 16)
TADIX-B	tactical data exchange broadcast
TAG	Technology Application Group
TBM	theater battle management
TCAS	traffic alert and collision avoidance system
TDMA	time-division multiple access
TIBS	Tactical Information Broadcast System
TRAP	tactical receiver applications
TSO	technical standard order
UAV	unmanned aerial vehicle
UHF	ultrahigh frequency
US	United States
USAF	U.S. Air Force
USCINTRANS	Commander-in-Chief, U.S. Transportation Command

List of Acronyms

USNO	U.S. Navy Observatory
UTC	universal time coordinated
VDL	VHF digital link
VDOP	vertical dilution of precision
VDR	CMU/VHF Digital Radio Subcommittee
VHF	very high frequency
VMF	variable message format
VOR	VHF omnidirectional range
VPE	vertical positioning error
WAAS	wide-area augmentation system
WAGE	Wide Area GPS Enhancement
XLS	Multi-Mode Landing System Subcommittee

Appendix A—Terms of Reference

A.1 BACKGROUND

Requirements for future air navigation systems are changing rapidly. Equipment and architecture needs for future international airspace are under study and, in some cases, are being specified. Most of the new requirements are being driven by the transition from ground-based navigation aids to space-based aids. The GPS 2000 directive, which directs installation of GPS equipment on most military platforms by 2000, will necessitate major budget outlays.

It is incumbent upon the Air Force to optimize the performance of navigation systems to allow and to enhance the performance of its aircraft in peacetime and wartime. The Air Force cannot afford to develop separate systems for navigation in international airspace and for military operations.

A.2 CHARTER

The SAB will conduct a study to determine the systems and technologies needed to bring the Air Force into compliance with future requirements. The study will also investigate the implications of the requirements and plans of other Services and of the civil community on those of the Air Force. To the extent possible the study will also address the role of GPS packages on commercial systems such as Iridium and Teledesic. Participants will include representatives from all military services, the civil government, and the civil operational and R&D communities.

A.3 TASKS

1. Determine the capabilities needed for flight in the future international airspace system
 - a. En route
 - b. Approach
 - c. Departure
2. Determine additional capabilities needed for successful mission completion
 - a. Operation from austere bases
 - b. Targeting
 - c. Weapon guidance integration
3. Evaluate current requirements, plans, costs, and schedules for achieving needed capabilities
4. Evaluate planned equipment
 - a. Aircraft
 - b. Ground
 - c. Space
 - d. Other (ships, ground vehicles ...)

5. Evaluate Air Force requirements relative to those of the other Services and civil users
6. Evaluate and determine needs for S&T support for GANS
7. Recommend
 - a. Technologies
 - b. New equipment
 - c. Equipment performance standards
 - d. Schedule
 - e. Modifications to existing platforms, avionics, space vehicles, and ground equipment
 - f. Methods for integrating mission and airspace navigation capabilities
 - g. Philosophy and architecture

The first meeting will review and, no doubt modify, the tasks and terms of reference.

Appendix B—Study Participants

Name	Affiliation
Chairman	
Dr. Gene McCall	Los Alamos National Laboratory
SAB Members	
Dr. Alison Brown	NAVSYS Corporation
Prof. Daniel Hastings	Massachusetts Institute of Technology
Mr. Burt Rutan	Scaled Composites, Inc.
Dr. Peter Swan	Motorola
Dr. Don Williams	Johns Hopkins University APL
Dr. Peter Worch	Private Consultant
Participants	
Lt Gen (Ret) Gordon Fornell	Private Consultant
Mr. Richard Arnold	Private Consultant
Mr. John R. Ackland	Boeing Commercial Airplane Group
Mr. Melvin Zeltser	Mitre
Mr. Robert Hawley	Booz-Allen Hamilton
Mr. Robert S. Morris	Gulfstream Aerospace Corporation
Mr. Brian McCarthy Sr.	Gulfstream Aerospace Corporation
Mr. Ron Beard	U.S. Naval Research Lab, Code 8150
Dr. Ivan Getting	Private Consultant
General Officer Participant	
Brig Gen Richard Reynolds	AFPEO/AT
Air Staff/MAJCOMS	
Maj Rex Porter	AFPEO/AT
Lt Col Mike Underwood	HQ AMC/XPRN
Ms. Patricia Salamone	HQ AMC/XPRN.
Col Bob Brooks	HQ ASC ² A/C ² F
Col J. Mike Arnett	HQ AFSPC/DRF
Lt Col Overbey	HQ AFFSA

Maj Don Oberdieck	HQ AFFSA
Maj Denny Peeples	SAF/AQPS
Dr. Aron Pinker	ANSER (SAF/AQPS)
Lt Col Mark Donahue	SAF/AQQM
Maj Greg Gerth	SAF/AQID
Col John C. Bedford	HQ USAF/XORFM
Lt Col Peter Geurtz	HQ USAF/XORFM
Maj Phil Iannuzzi	HQ USAF/XORFM
CAPT Bud Jewett	CNO N88OG2
CAPT (Ret) J.R. Calhoun	Booz-Allen Hamilton
CDR Frank P. Olic	CNO N885F
Mr. Barry Schwoerer	ARINC (NAWC-AD PAX)
Mr. Glenn Colby	NAWCAD Pax River
CAPT Paul Novak	PMW 187
Mr. Garth Van Sickle	DSC Corp
Col Steve Henry	GATO/C ² SPO
Study Tech Writer	
Capt Dan Uribe	USAFA/DFP
SAB Executive Officer	
Capt Tim Kelly	HQ USAF/SB

Appendix C—Panel Site Visit Locations/Meetings

Date	Location
1. 13-14 March	Kickoff Meeting at ANSER
2. 9 April	Patuxent River NAS, MD
3. 17 April	Federal Aviation Administration, Washington, DC
4. 18 April	Panel Meeting at ANSER
5. 1 May	Panel Meeting at Randolph AFB, TX
6. 2 May	American Airlines, Dallas/Ft Worth
7. 20-21 May	Air Mobility Command, Scott AFB IL Included industry briefings from UPS, Boeing, Rome Labs, Rockwell Collins, Honeywell, and Lockheed Martin
8. 18-19 June	AF Space Command, Peterson AFB, CO
9. 3 July	International Civil Aviation Organization, Montreal
10. 16 July	ARINC, San Diego, CA
11. 22 July	VTC with Eurocontrol, Brussels, Belgium
12. 14-25 July	Beckman Center, Irvine, CA

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Appendix D—Distribution List

Headquarters Air Force		
SAF/OS	1	Secretary of the Air Force
AF/CC	1	Chief of Staff
AF/CV	1	Vice Chief of Staff
AF/CVA	1	Assistant Vice Chief of Staff
AF/ST	1	Chief Scientist
AF/TE	1	Test and Evaluation
AF/LRP	1	Long Range Planning
AF/HO	1	Historian
Assistant Secretary for Acquisition		
SAF/AQ	3	ASAF, Acquisition
AQX	1	Management Policy and Program Integration
AQL	1	Special Programs
AQI	1	Information Dominance
AQP	1	Global Power
AQQ	1	Global Reach
AQS	1	Space and Nuclear Deterrence
AQR	1	Science, Technology and Engineering
Assistant Chief of Staff, Intelligence		
AF/IN	1	ACS, Intelligence
INX	1	Plans and Policy
INR	1	Resource Management
Deputy Chief of Staff, Plans and Operations		
AF/XO	1	DCS, Plans and Operations
XOO	2	Operations
XOR	2	Operational Requirements
XOF	2	Forces
XOX	2	Plans
XOM	2	Modeling, Simulation, and Analysis

Deputy Chief of Staff, Logistics		
AF/LG	2	DCS, Logistics
Deputy Chief of Staff, Command, Control, Communications, Computers		
AF/SC	1	DCS, C ⁴
SCM	1	C ⁴ Mission Systems
SCT	1	C ⁴ Architectures, Technology and Interoperability
SCX	1	Plans, Policy and Resources
Directorate of Programs and Evaluation		
AF/PE	1	
AFPEO/AT	1	Airlift and Trainers
AFPEO/SP	1	Space Programs
AFPEO/FB	1	Fighter and Bomber Programs
AFPEO/C ³	2	C ³ Programs
AFPEO/BA	2	Battle Management
AFPEO/WP	2	Weapons
AFPEO/JL	2	Joint Logistics Systems
Office of the Secretary of Defense		
OUSD (A)	1	Under Secretary for Acquisition
USD (A)/DSB	1	Defense Science Board
DDR&E	3	Director, Defense Research & Engineering
ASD/C ³ I	1	Assistant Secretary of Defense for C ³ I
OUSD (AT)	1	Deputy Under Secretary for Advanced Technology
BMDO	1	Ballistic Missile Defense Organization
DARO	5	Defense Airborne Reconnaissance Office
DARPA	5	Defense Advanced Research Projects Agency

Other Air Force		
AFMC	1	Air Force Materiel Command Section
ST	2	Science and Technology
WL, AL, PL, RL, OSR	5 ea.	Labs and AFOSR
ESC, ASC, HSC, SMC	1	Product Centers
ACC	3	Air Combat Command
AMC	1	Air Mobility Command
AFSPC	1	Air Force Space Command
PACAF	3	Pacific Air Forces
USAFE	3	U.S. Air Forces Europe
AFOTEC	1	Test and Evaluation Center
AFSOC	1	Air Force Special Operations Command
AIA	2	Air Intelligence Agency
NAIC	1	National Air Intelligence Center
USAFA	1	Air Force Academy
AU	1	Air University
AFIWC	1	Information Warfare Center
AFIT	1	Air Force Institute of Technology
NGB/CF	1	National Guard Bureau
AFSAA	5	Air Force Studies and Analysis Agency
Army		
ASA (RD&A)	1	Assistant Secretary of the Army for Research, Development and Acquisition
ASB	3	Army Science Board

Navy		
ASN (RD&A)	1	Assistant Secretary of the Navy for Research, Development and Acquisition
NRAC	1	Naval Research Advisory Committee
NAWC	3	Naval Air Warfare Center
NRL	3	Naval Research Laboratory
ONR	2	Office of Naval Research
Joint Staff		
JCS	1	Office of the Vice Chairman
J2	1	Intelligence
J3	1	Operations
J5	1	Strategic Plans and Policies
J6	1	C ³ Systems
Other		
Study Participants	1 ea.	
Aerospace Corporation	2	
ANSER	2	
Mitre	2	
MIT Lincoln Lab	2	
RAND	2	
Air Force Science and Technology Board	1	
Naval Studies Board	1	